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THE
NATURAL HISTORY OF PLANTS

THEIR FORMS, GROWTH,
REPRODUCTION, AND DISTRIBUTION

FROM THE GERMAN OF
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WITH ABOUT 2000 ORIGINAL WOODCUT ILLUSTRATIONS AND SIXTEEN PLATES IN COLOURS

HALF-VOLUME IV.



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Under these circumstances it is a matter of indifference whether 10 per cent or only traces of lime or silica can be demonstrated in the soil, and the hypothesis that plant-species which grow on limestone fail to grow on slate because they are not able to supply their need of calcium, or that the plants growing on slate cannot flourish on limestone mountains because they cannot obtain the necessary amount of silica, must be abandoned, as well as the assumption that these substances when absorbed as food serve as a stimulus to change of form.

I strongly supported this latter hypothesis at the time, and thought I should be able to strengthen and confirm it by careful cultural experiments. Seeds of several species which demand lime were sown in soil containing hardly perceptible quantities of lime, and the seedlings were watered with water devoid of calcium; in another place seeds of species demanding a silica-containing substratum were placed in soil which contained much limestone, and the seedlings were watered with lime-water. At first it seemed as if an alteration of form had actually taken place in some individuals. But this was a mistake, or rather, the alteration only consisted in the greater or less luxuriance of the foliage, lengthening or shortening of the stem, abundant or scanty development of flowers and the like. But no actual change of form which would be retained by their descendants could be obtained. The species of plants accustomed to lime, grown on a soil devoid of lime, presented a miserable appearance, with scanty flowers which ripened only a few seeds, whilst the silica-demanding species grown on lime-containing soil soon withered and died without flowering at all. The change of form, indeed the actual interchange I had anticipated between the closely allied species which grow on the two rocky substrata in a state of nature, did not occur at all.

If we still take the case of siliceous and calcareous plants, and regard the soil as the source of free inorganic substances which influence the plants, we are forced to assume that greater quantities of one substance will be injurious to one or other of them. The absorbent cells have the capacity of choosing between the substances at their disposal, but this capacity has a definite limit in every species. The cells can absorb as much as they require from a very weak solution of common salt, soda, gypsum, calcium bicarbonate, &c., but a concentrated solution of these salts may injure and destroy their structure and function. If it is allowed to act for any length of time on the cells whose function is to absorb inorganic nutriment, the death of the whole plant will inevitably result. If the Moss which grows on blocks of granite is watered with a saturated solution of gypsum; if the soil into which our Meadow-grasses send their roots is watered with a saturated solution of common salt; or if the humus in which the plants of an upland moor grow is mixed with sodium carbonate or calcium bicarbonate, the plants invariably perish, and the same mineral substances, which in a very weak solution are needful, or at any-rate harmless, become poisonous when the solutions are concentrated. The fact that one species of plant prefers this and another that mineral substance (see vol. i. p. 73), however, renders it probable that the injurious effect of materials in large quantity in the soil varies, that a large quantity of,

common salt would be injurious to one species, and an abundance of sodium or potassium salts to another. From the present standpoint of our knowledge concerning the absorption of inorganic materials by plants, therefore, Unger's classification, especially the expressions silica-demanding and silica-preferring, is no longer suitable, and it would be more to the purpose to speak of plants which are injured by lime, potash, &c.

The difference in the vegetation on the closely adjoining limestone and slate mountains met with in so many places in the Alps, and so well seen in the neighbourhood of Kitzbühel, where the climatic influences on the two ranges are identical, can be accounted for most satisfactorily in the following way. Plant-species which demand or prefer a siliceous soil are absent from limestone mountains wherever their roots would be exposed to more free lime than is beneficial; if present they would be weakened, and thus vanquished in the struggle with their fellows, to whom the larger quantity of lime is harmless, and they would eventually perish. These plants flourish luxuriantly, however, on slate mountains, because there the soil does not contain an injurious amount of lime. The absence of species, demanding or preferring lime, from slate mountains can be explained in the same way. When seeds are brought thither by the wind from the neighbouring limestone mountains and germination commences, their further development is visibly retarded; they dwindle wherever there is not much lime, and are overgrown and suppressed by the siliceous species which flourish there so luxuriantly. The brown or black mass formed by the decomposition of dead plant residues, known as humus, plays a very important part in the contrasting vegetation on limestone and slate mountains. To obtain a true idea of its significance it must first be pointed out that three distinct stages can be distinguished in the development of a continuous and intricate plant-covering. To the first stage belong the plants which settle down on the bare earth content with a substratum wholly devoid of humus; in the course of time they conquer the most barren rock, the barest boulders, and the dreariest shifting sands. The species of this group belong chiefly to the Lichens, Mosses, Grasses, Pinks, Crucifers, House-leeks, Saxifrages, and Composites, whose spores, seeds, and fruits are exceptionally well adapted for wind distribution, and can be transferred with ease to the steepest slopes and the most uncompromising crags. The second stage includes plants which require a moderate amount of soil mixed with humus; they establish themselves on the ground prepared by the first settlers, wresting it from them and taking possession, and then suppressing and overgrowing them entirely. These plants belong to very different families, whose distribution and establishment are effected in very many ways to be described subsequently. The third stage of development consists of plants for which the abundant humus stored up successively by the plants of the second stage is absolutely indispensable. Bog-moss, Lycopodiums, Sedges, and Heaths form the chief part of this stage. In the course of years the amount of inorganic materials in the soil which supports the plants of the third stage continuously diminishes. Plants which require a large quantity of inorganic salts languish, and are, moreover,

overcome by saprophytes which find a suitable habitat there and flourish in abundance. The decayed portions of Saprophytes contain relatively little inorganic material. No trace of lime (in particular) is to be found in their ash. In this way a superficial layer of humus is formed which actually excludes a large number of plants. The next deeper layer may contain a considerable quantity of inorganic salts, but they are valueless to plants rooted in the upper (humus) layer, as they cannot penetrate it. It has been shown by experiment that pure humus possesses the power of holding back materials which are soluble in water. It possesses this property to such an extent that if salt solutions are filtered through a layer of humus the water which escapes below is almost pure. It is therefore impossible for inorganic substances from the deeper layers of the soil, much less from the underlying rock, to reach the surface layer of humus in solution by diffusion; and if some mineral ingredients are not introduced by irrigation or flooding, the upper layer of soil consists of pure humus on which only saprophytic plants can flourish.

The formation of such layers of humus occurs much more easily and quickly on slate mountains than on limestone, because in the former the rock and the products of its decomposition retain water much better, and a uniform saturation promotes the development of humus, and also because on slaty soil the second stage of the development of the plant-covering consists of plants which require very few inorganic food-substances, and accordingly very few inorganic materials are yielded by the humus, which originates at the cost of the decaying portions of these plants. But a thick stratum of pure humus may also arise in course of time on limestone mountains. Only the soil must be uniformly moist in that spot, and neither sand nor mud must be deposited on it. If these conditions are fulfilled a deep humus will gradually spread itself over limestone rocks and débris in the third stage of development, the superficial layer of which will contain no trace of lime, but will afford an excellent soil for silica-loving plants (*i.e.* for those to which lime is injurious). The isolated occurrence of so-called siliceous or slate-plants on limestone mountains, even in the middle of a patch of plants which are characteristic of a limestone soil, may be naturally explained in this fashion.

The water which moistens the rock and soaks the soil has, apart from its mechanical action, the important function of opening up mineral substances and of forming solutions from which the absorbent plant-cells may take their choice. The atmospheric water which penetrates into the earth from above is especially valuable as a solvent on account of the carbonic acid gas it contains. It is immeasurably more valuable to every part of the soil which is riddled by the roots of living plants than the soil-water, so poor in carbonic acid, which collects on impervious strata of the soil and soaks upwards through the superficial layers.

The power of the soil to retain water depends mainly on the extent of breaking up undergone by the rock whose disintegration has formed the soil and upon the amount of clay which has arisen from this disintegration. But the amount of humus which in course of time has mixed with the disintegration and the decomposition products of the underlying rock is also an important factor, and thus very

complex conditions arise which render the estimation of the soil's capacity for retaining water very difficult. If permeable sandy soil, poor in humus, is deprived of ground water and is dependent for its moisture solely on the atmosphere, the plants growing in it will be retarded in their development if rain and dew are absent for any length of time, and their outward appearance will be altered by this restriction of growth. Annual plants subjected to a lack of moisture in the soil just at the time when their growth should be at its maximum, show best how far these alterations will go. The stem-structures remain short, the foliage-leaves shrink to their smallest extent, and no lateral shoots are developed. Only a few, or perhaps only one, of the flower-buds mature; it is small, opens comparatively very early, and the whole plant has a dwarfed aspect. Annual plants of the Poppy (*Papaver Rhæas, somniferum*), Pheasant's Eye (*Adonis æstivalis, flammea*), Corn-cockle (*Agrostemma Githago*), Cornflower (*Centaurea Cyanus*), and common Groundsel (*Senecio vulgaris*) grown on a dry soil differ from plants grown in the same place, but in a damp year, to such an extent in the size of all their parts that at first sight they might be mistaken for other species. A clay soil which retains water is less exposed to danger of too great dryness, but if it is not mixed with humus, and therefore loosened, it has the disadvantage that the water it contains cannot take up the inorganic foods quickly enough and in sufficient quantity for the requirements of the plants. This drawback explains the surprising fact that plants grown on heavy wet clay soils have a dwarfed appearance exactly like plants growing on dry sandy soil. In regions liable to flooding by streams and rivers where not infrequently sandy and clay soils, in all degrees of porosity and admixed with humus in all possible proportions, are to be met with within a few yards of one another, certain species of plants are to be found growing near together in all imaginable degrees of size, e.g. *Aster Tripolium*, *Bidens cernua* and *tripartita*, *Polygonum lapathifolium*, *Rumex maritimus*, *Veronica Anagallis*. In places where the seedlings cannot find enough free mineral foods, in spite of the abundant moisture in the soil, the stem rises to some 3–8 cm.; in places which favour the absorption of food, to some 50–80 cm. We will describe only one species, *Veronica Anagallis*, more in detail. Plants of this species are found with stems 3–5 cm. high and 0.5 mm. thick, with foliage-leaves 6–12 mm. long and 5–6 mm. broad when fully developed. The number of flowers in one inflorescence is about 4–5, the calyx and ripe capsular fruit measure 3 mm. in length. Contrasting with these are plants with stem 30–50 cm. high and 7–8 mm. thick, whose fully-formed leaves are 80 mm. long and 35 mm. broad. There are 40–50 flowers in each inflorescence, and the calyx and ripe capsule measure 4–5 mm. in length. Generally speaking these plants are about ten times as large as the others. If the soils which give rise to such surprising differences in size are examined it will be noticed that the dwarfed specimens are rooted in a heavy soil devoid of humus, while the large luxuriant plants flourish in a clay soil which is mixed with plenty of humus, and is therefore very open. Obviously the plants could not obtain from the heavy clay soil what they required for the structure of a vigorous plant, even although the

ground was well moistened and warmed; but this they could obtain in abundance from the saturated clay soil containing the humus.

It has been already stated that the ground water is less favourable for vegetation than rain and dew on account of its paucity of carbonic acid. But the moistening of the ground by water which wells up from below brings other evils in its train. By this means the soil is over-saturated for a long time, a condition which the roots of most land-plants will not tolerate. When it remains stationary for a long while potassium and sodium salts, and, under certain conditions, humous acids pass into it from the wet earth in quantities anything but advantageous to the plants. Vegetation, therefore, exhibits a scanty growth in places where the ground water influences the stratum of soil penetrated by roots, and it usually consists of comparatively few species.

In low-lying regions, where the ground water rises to the surface, we have the formation of lakes and ponds with variable water-level. Sometimes the plants growing in such places are quite submerged, while at other times their stem and leaves are above water. Land plants do not take kindly to this. Most of them cannot survive very long immersion; they become suffocated, die, and decompose under water in a few days. Only a few species have the remarkable power of growing equally well below or above water, and these are, of course, extremely interesting on account of their form. In accordance with the great contrast presented by the external conditions of life to which these species are temporarily exposed we have a fundamental change both in their outward appearance and in the internal structure of their several organs. In order that the stem and leaves should be held in the best position by the flowing water, the mechanical tissue in submerged varieties of these species is much reduced (see vol. i. pp. 424 and 665). They are also devoid of the contrivances which usually regulate transpiration, since no evaporation occurs under water. Stems grown under water consequently appear limp and flaccid when taken out of it; their leaves, when compared with those growing in the air, are much weaker and more delicate. They have no gloss, but are brighter green in colour, and in the air they collapse and dry up in a very short time. A vertical section through the leaf shows that the number of cells between the upper and lower epidermis is much reduced, and that the cells are shortened in a direction perpendicular to the leaf surface. The foliage-leaves of *Veronica Beccabunga*, when grown under water, are hardly one-third as thick as those grown in the air, and between the upper and lower epidermis there are only 4-5 layers of short cells, while in corresponding leaves of aerial plants there are 10-12 cell-layers and a distinct division into palisade and spongy parenchyma (see vol. i. p. 279). The shape of the leaf is also much changed under water. In *Veronica Beccabunga* the difference in aerial and submerged leaves is very slight, consisting only in the shortening of the petiole and in the marginal teeth becoming less marked. In *Veronica Anagallis*, likewise, the alteration in shape is inconsiderable, but in many others it is very noticeable, and we shall return to it when speaking of the influence of light.

Plants rooted in the mud of a river-bed, the stems and leaves of which are surrounded by rapidly-flowing water, must possess corresponding strength if they are not to be torn. In comparing two plants of the same species, the one growing in the still water of a deep lake, the other in a rapidly-flowing stream, it will be noticed that the walls of the superficial cells of the latter have become strongly thickened, and that strong bundles of bast-fibres have developed in the cortex of the stem, while in the former only the weakest traces of bast-fibres can be seen. The extraordinary length of stem, petiole, and leaf-blade is also very surprising in plants which grow in rapid water. The Pondweed *Potamogeton fluitans*, the Rushes *Juncus lamprocarpus* and *supinus*, the Grasses *Agrostis stolonifera* and *Glyceria fluitans* are very instructive examples. A plant of the last-named Grass growing on damp soil on the edge of a stream over the water had linear, bluntly-pointed leaves, whose sheaths were on the average 15 cm. long, the blades 23 cm. long and 8.5 mm. broad. After this plant had been submerged under rapidly-flowing water in the following year, leaves unfolded, which tapered gradually to a point, with a sheath having a mean length of 47 cm., and blades 73 cm. long but only 5 mm. broad. The blades produced in running water were three times as long and actually rather narrower than in the air. There was no difference in the number of strands traversing the blade, but they were nearer to one another than in the aerial leaves. The Arrow-head (*Sagittaria sagittifolia*), which usually grows on the muddy bottom of shallow lakes, raising its leaves above the still water, has gained its name from the likeness of its leaf-blade to an arrow. If it is planted in the bed of a rapid stream so that the leaves during their development are exposed to a vigorous current, the leaf-blade is almost entirely suppressed. What still remains has the form of a spade, but not infrequently all trace of lamina is wanting. The petiole, however, lengthens to 70 cm., and forms a limp, flat, pale-green ribbon 1-2 cm. broad, which might easily be mistaken at first sight for the leaf of *Vallisneria*.

Another remarkable change which is effected by submerging growing plants is the non-development of the epidermal structures called hairs, so that the leaves and stems of submerged plants always appear smooth. The suppression of hair-structures is very noticeable in the aquatic variety of *Polygonum amphibium*. In aerial plants of this species the leaves have short petioles, are lanceolate in shape, and are covered thickly with short hairs, which are rough to the touch; while the aquatic plants have long-stalked, broadly-linear leaves completely smooth on both sides.

The humidity of the atmosphere has a marked effect on the form of land plants. Transpiration, which is so deeply concerned in all the vital processes, is carried on very slowly in air which is almost or quite saturated with water-vapour. If plants of a species which usually grows in dry air come into a humid atmosphere, they must be furnished with means for aiding evaporation. On the other hand, plants which grow in dry air must be protected against excessive transpiration. The aids and protective measures were so minutely described

in vol i. pp. 284 and 307, that it is needless to repeat them here; but it should be noted that the capacity of plants to construct their tissue as need requires, either for aiding transpiration or for protection against excessive evaporation, is very limited. It must also be pointed out that it is very difficult to distinguish clearly between the direct effect of the humidity of the air and the effects of other influences. Heat and light, as well as the amount of moisture in the soil, are intimately connected with the humidity of the air, but the relations are difficult to estimate. To a certain extent they are interchangeable, and therefore, in most instances, it is impossible to say which external influence is the cause of any particular alteration in the tissue concerned in transpiration. For the answer to the chief question, whether it is possible for a change in the conditions of life to cause an alteration of form in the sense of an adaptation, it is really a matter of indifference which influence causes the visible effect. Only here, as in so many other cases, matters are simplified if a certain partiality is permitted in experiments for solving these difficult questions, and if the interwoven influences of soil and climate are treated separately.

The effect of heat on growing plants was discussed at vol. i. p. 523. It only remains to say here that the formation of starch and other reserve-foods, as well as the formation of sugar in fruits, is largely connected with heat. Fruits of the same species which ripen under a higher temperature differ greatly in the amount of sugar they contain from those ripening at a lower temperature. It is generally accepted that the size also of the stem, foliage, flowers, and fruit is influenced by heat. The changes which occur when plants in flower, after being for some time in a very warm room are transferred into a cooler room, the other conditions remaining the same, are in particular now recognized. When a large-flowered bulbous plant, *e.g.* the Belladonna Lily (*Amaryllis Belladonna*), is transferred to a cold greenhouse after opening its first flowers in a warm one, the flowers it here develops at a lower temperature are almost a third smaller than those produced in the warm house. But when the first flowers open in the cold, and the later ones in a warm atmosphere, the former remain small and the latter are larger in size. It is important to emphasize this circumstance in order that the phenomenon here exhibited may not be mistaken for another, in case we should be led to think that the flowers of a plant which first unfold are larger than those which succeed them even when there has not been the slightest alteration in the conditions of light, heat, humidity, &c.

It is particularly instructive, when examining the effect of heat on the form of a species, to compare plants grown in water of different temperatures but under conditions otherwise similar. In mountainous districts the springs on the same mountain slope have a different temperature according to their elevation, and yet the same species of plants may be found growing in springs at the foot and high up on the mountain. Let us take as examples plants of *Cardamine amara*, *Myosotis palustris*, *Pedicularis palustris*, and *Veronica Beccabunga*. These species grow at the foot of the Patscherkofel, near Innsbruck, in the bed

of streams with a mean temperature of 10.2°C ., but they also flourish in a stream above the tree-line, at a height of 1921 metres above the sea-level, known as the "Kreuzbrunnen". Comparing plants of the same species growing under the influence of these different temperatures, the following differences are to be noted:—Plants of *Veronica Beccabunga* growing in spring water at a temperature of 10.2°C . were 20–50 cm. high, and displayed 4–6 internodes between the bottom in which they were rooted and the level of the first inflorescences. The internodes of the stem were 60–120 mm. long and 5 mm. thick; the leaves springing from the middle of the plant were 40–60 mm. long, 20–25 mm. broad, and each of the flower racemes had 12–16 flowers. Plants growing in the spring water at a temperature of 4.2°C . were 10–15 cm. high with 4–6 internodes between the ground and the level of the first inflorescences. The internodes were 15–30 mm. long and 10–12 mm. thick, and each inflorescence had 12–16 flowers. *Cardamine amara*, *Myosotis palustris*, and *Pedicularis palustris* behaved similarly. There seemed to be no alteration in the form of the leaves and flowers; the corollas assumed a rather deeper tint in the Kreuzbrunnen; *Myosotis palustris*, which was 20 cm. high at the foot of the Patscherkofel, was 4–5 cm. high in the Kreuzbrunnen, and closely resembled the *Eritrichium nanum* of the Southern Alps in the deep blue of its corollas. *Cardamine amara*, in the same cold spring, in addition to the shortening of its internodes and diminution of its foliage-leaves, displayed a red colour on the outside of its white petals which was not present in plants at lower levels.

The powerful influence of light on the development of plants was discussed at vol. i. p. 371. The question now before us is how far bright and subdued light are able to alter the size, form, and colour of plants. The following is a general review of what has been ascertained in the matter from experiments and direct observation of nature. When plants of a species develop in subdued light they always have higher stems and longer leaves than when grown in bright light, provided, of course, that the conditions of moisture and temperature have been as far as possible identical. This difference is especially noticeable in comparing two plants of a species, one of which has developed in the dim light of a greenhouse in the short days of winter, the other in an unshaded place in the open country during the summer when the light lasts for 16–17 hours every day. The former has a lank thin stem, delicate yellowish-green leaves, and either none of its flowers unfold or else they have a weak appearance and their corollas are pale and flaccid. The illuminated plant has, on the other hand, a compact vigorous stem, dark green leaves, and unfolds a multitude of bright-hued flowers. One only of the large number of experiments which have been performed for the purpose of determining this matter definitely will be mentioned here—one indeed which shows how far the form of the flowers also may be affected. Seeds of a biennial Saxifrage, *Saxifraga controversa*, which were sown in several flower-pots filled with similar soil, produced numerous young plants. A pot with six of these young plants was taken in the autumn into the hot-house; another, likewise containing

six young plants, passed the winter under a thick coat of snow in the open. At the beginning of December the six plants in the hot-house sent up from the centre of their small leaf-rosettes slender stalks 10 cm. high, whose upper internodes were 22 mm. long and 1 mm. thick. The stem-leaves were yellowish, entire, elongated, 6-7 mm. long and 2 mm. broad; calyx-tube 4 mm. long, 13 mm. broad; calyx-teeth 2 mm. long, 1.5 mm. broad; petals 3.5 mm. long, 2 mm. broad; stamens 1 mm. long. It was noted that lateral axes only developed in the axils of the upper stem-leaves, and that the buds of the lateral shoots in the lower leaf-axils atrophied. In the following May strong stems 6 cm. high were sent up from the leaf-rosettes of the plants which had wintered under the deep snow in the open; their upper internodes were 12 mm. long and 2 mm. thick. The stem-leaves were somewhat broadened in front with dentate margin, red in colour, 5 mm. long and 3 mm. broad. The measurements of the parts of the flowers were:—Calyx-tube, 2 mm. long, and 2 mm. broad; calyx-teeth, 1.5 mm. long, 1 mm. broad; petals, 2.3 mm. long, and 2 mm. broad; stamens, 1 mm. long. From the axils of the stem-leaves flower-bearing shoots developed, which, like the parts of the main stem exposed to the sun, were coloured red. Here then the alterations which certainly are due to the various light influences consist not only in the lengthening and shortening of the stem- and foliage-leaves, but the flowers are correspondingly changed. The petals of the flowers which opened at the New Year when the days were shortest were not only relatively but actually narrower than those which belonged to flowers which opened in the early summer when the days were longest.

It has already been stated that the elongation of the leaves and the division of the leaf-lamina into long narrow segments in submerged leaves is associated with the diminution undergone by the light in passing through the water (see vol. i. p. 665). The elongation of submerged leaves is very well seen in the water Starwort (*Callitriche*) and Mare's-tail (*Hippuris*). In the latter the linear submerged leaves are thirty times as long as they are broad, while the length of the aerial leaves is only 7-9 times their width. In *Roripa amphibia* the leaves which develop under water are deeply cleft compared with those produced in the air. The aerial leaves of this Crucifer are linear-lanceolate, about ten times as long as broad, with finely toothed margin. Under water the leaves have an elliptical shape, are 2-3 times as long as broad, and the lamina is cleft almost down to the midrib in narrow segments 2-3 cm. long, like a comb or feather. The aerial leaves of the whorled Waterwort (*Elatine Alsinastrum*) are grouped in whorls of three. They have an ovate shape, and their margins are finely notched. Each is traversed by 3-5 veins. The leaves developed under water are divided almost their whole length into 3-4 narrow linear segments, and each whorl looks as if it were composed of twelve leaves. Each segment is smooth round the edge, and traversed only by one central vein. The difference between the aerial and submerged leaves of the white-flowered Crowfoots (belonging to the *Batrachium* section of the genus *Ranunculus*) is even more surprising. Plants of these Crow-

foots which have developed on muddy but not inundated ground display three- or five-cleft leaves whose segments are light green in colour, shiny, and almost fleshy, and spread out flat. When these plants are grown under water the leaves appear quite different; they become divided into numerous thread-like or hair-shaped segments which have a dark-green colour, and the polished surface has entirely disappeared.

The shade afforded by stones, loose earth, undergrowth, and neighbouring bushes and shrubs acts on growing stems, foliage-leaves, and flowers just in the same way as the light-subduing layer of water. In a place near my country house which was formerly used for storing wood and dry twigs, but which had remained unused for a long time, the Creeping Thistle (*Cirsium arvense*) had established itself and formed an intricate growth. The crowded stems attained a height of 80 cm. at the time of flowering and fruit ripening. In the winter of 1885 wood was again stored there in piles 150 cm. high. When, early in the following summer, the new shoots of the Thistle began to spring up they were obliged to content themselves with growing through the dark chinks between the blocks of wood. Many were thus forced to bend and twist, and finally came against some insurmountable obstacle so that they dwindled in the crevices of the wood-stack without ever reaching the light. Others again which were able to find a fairly straight road through the crevices grew up until they reached the surface of the wood-heap, they then continued to grow 50 cm. higher and unfolded large foliage-leaves on this upper portion. They also developed branches with flower-heads, and from a distance it looked as if a group of Thistles had grown on the top of the wood-stack. The stems had attained a height of 2 metres. The lower internodes were twice as long as usual, the foliage-leaves which sprang from the stalk inside the dark crevices were small, yellowish green, and the buds in their axils did not develop. The Cow-berry (*Vaccinium Vitis-Idæa*) behaves similarly when its shoots are obliged to grow up to the light through dead tree-trunks. Shoots which force their way in the dark between the bark and the wood of the trunk may reach the height of a metre, while neighbouring ones, springing directly from the soil of the forest are only 15 cm. high. The shoots inside the bark have a reddish colour, and they bear small pale scales instead of dark-green foliage-leaves.

From the creeping stems of the White Clover (*Trifolium repens*) spring erect petioles terminating in three leaflets, and an erect angular stem bearing a flower-head. In sunny places, especially where no neighbouring plants cast a shade, the petioles reach a length of 8 cm., and the stem of 10 cm. But if dense bushes overshadow the Clover, the petiole and stem elongate until the leaflets and capitulum they bear reach the light. Under these conditions petioles 28 cm. long have been found, and stems attaining a height of 55 cm. An extraordinary elongation also occurs in the radical leaves of the Dandelion (*Taraxacum officinale*) in places where high Grasses and thick bushes shade the moist soil. In the open the leaves reach a length of 20 cm., but in the shade they become twice or three times as long. The lower part of the leaf lengthens most, the free end is comparatively

very little altered, and in the central portion the only change is that the lobes and teeth become shorter and less clearly marked.

In order to ascertain the effect of covering plants with earth, numerous bulbs of a species of Tulip (*Tulipa Gesneriana*) were planted at the same depth in one garden bed, and in another some corms of the Spring Crocus (*Crocus vernus*). Earth was heaped over these bulbs and corms in successive heights of 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 cm. Naturally the leaf-tips and flower-buds were first seen in the places where the bulbs were only covered with 5 cm. of soil; in both beds the development was delayed—in the other cases in proportion to the height of the soil above the bulbs. Some flower-buds of the Crocus appeared above the 20 cm. of soil, one of the Tulip above the 30 cm. Numerous leaf-tips of the Crocus appeared above the 35 cm., and a few of the Tulip above the 40 cm. of soil. The perianth-tube, the peduncle and the foliage-leaves were almost twice as long as those which had developed under only 5 cm. of soil. The flowers were smaller, and unfolded just above the soil; the leaves were narrower and pale yellow in colour as far up as they were covered with the soil. Neither the Crocus nor the Tulip raised their leaves higher than 40 cm. Apparently the reserve-materials stored in the corm and bulb-scales were not sufficient for a further elongation. The stems and leaves of the Crocus and Tulip thus exhibit alterations similar to those observed in the sprouts of Potato-tubers in a dark cellar.

We should expect that if moisture and lack of light produce elongation of shoots and various alterations in leaves, a brilliant illumination would have the opposite effect on growing plants. This is indeed the fact. Plants which have been for a year in the shade and have been placed at the beginning of their development in the following year in the sun display shorter internodes and firmer leaves; they blossom more abundantly, the flowers are of a deeper hue, and in many cases a covering of hairs is formed over the green portions. It is not necessary to mention how far transpiration, which is much more active in the sun than in the shade, is concerned in this; these alterations are certainly produced in the end by sunlight.

The effect of brilliant illumination is best seen by comparing plants grown from similar seeds at different elevations, but under identical conditions in other respects. The results obtained in my experimental garden near the summit of the Blaser in the Tyrol, at a height of 2195 m., during the years 1875–1880 illustrate this very fully, and I will briefly recount them here. The seeds of some annual plants were sown in September. The beds were covered with a layer of snow a metre thick throughout the winter. The germination of the seeds took place in the following year soon after the snow melted between the 10th and 25th June. The seedlings therefore developed during the time when the sun was highest and the days longest, and the young plants were exposed to a temperature not lower but rather higher than that enjoyed by plants from similar seeds which began to develop in the experimental beds of the Vienna Botanic Garden in March, when the daylight lasted about 12 hours. The seedlings of several species (e.g. *Gileia tricolor*, *Hyoscyamus albus*, *Plantago Psyllium*, *Silene Gallica*, *Trifolium incarnatum*) were

killed by the isolated frosts which occurred in each of the six years of the experiment, not only in the last week of June, but during July and August; but others (e.g. *Agrostemma Githago*, *Centaurea Cyanus*, *Iberis amara*, *Lepidium sativum*, *Satureja hortensis*, *Senecio vulgaris*, *Turgenia latifolia*, *Veronica polita*, *Viola arvensis*) only underwent a short temporary stoppage of growth from this cause, and opened their flowers at the end of August and beginning of September. In the plants of some species (e.g. *Senecio vulgaris*, *Veronica polita*, *Viola arvensis*) ripe seeds capable of germinating were formed in September. The flowering specimens, in comparison with those which had grown during the short days of the spring exposed to numerous night-frosts in the Vienna gardens, displayed extremely shortened internodes. The number of internodes was also lessened, or rather, fewer were developed. For example, where 10 internodes developed in an experimental plant in Vienna, in the Alpine garden a corresponding plant would only have 5-6. The same was true of the development of the flowers. While in a plant of *Viola arvensis* in Vienna the axillary buds of the first six foliage-leaves were suppressed and flowers were not produced until the seventh and eighth leaves, flowers grew from the third and fourth axillary buds in the same species of plant grown in the Alpine experimental garden. The number of flowers on a plant was less, the petals were smaller on the average, and, generally speaking, the annual plants in the Alpine garden had the same appearance as those grown in the plain on dry, sandy soil described on p. 500. It has already been stated on p. 453 that some of the species which are annuals in the valley and on the plain do not die in the autumn in the Alpine garden, but remain alive through the winter and in the following year develop new shoots from the stem.

To describe the alterations undergone by biennial species in Alpine regions we will take *Libanotis montana* (an Umbellifer) as an example. Its stem in the Alpine garden was 16-24 cm. high and developed 5 internodes which were 2-5 cm. long. From the axils of the 5 green stem-leaves sprang lateral shoots which did not branch but terminated in a single umbel, so that the plant only bore 5 umbels altogether. The plants grown from similar seeds in the Vienna Botanic Garden exhibited a stem more than a metre high with 10 internodes each 10-20 cm. long. No lateral shoots were produced from the axils of the lower stem-leaves. Those from the axils of the middle and upper leaves were branched and bore several umbels. On an average a plant had about 20 umbels altogether.

Over 300 species of perennial plants were grown in the Alpine experimental garden. Only 32 of them blossomed, however. Those whose flowers usually precede the foliage-leaves were in full blossom at the beginning of July, the others, which had to develop a leafy stem before their flowers appeared at the top or in the axils of the leaves of this stem, did not flower until the end of August and beginning of September. Three species of the latter kind will be more particularly treated of here; one species whose stem bears only a single leaf and is terminated by a single flower (*Parnassia palustris*), one whose stem is beset with decussate leaves and terminates in a loose inflorescence composed of small cymes (*Lychnis*

Viscaria), and a third whose stem bears alternate leaves and whose flowers are grouped in capitula (*Pyrethrum corymbosum*).

The Grass of Parnassus (*Parnassia palustris*) from the Alpine garden, when compared with plants grown in the experimental beds of the Vienna Botanic Garden, showed the following measurements:—

	Vienna Botanic Garden.	Experimental Garden on the Blaser.
Height of stem	20-27 cm.	5-9 cm.
Dimensions of leaf	3.3 cm. long, 2.4 cm. broad.	1.0 cm. long, 0.6 cm. broad.
Diameter of flower	2.8-3.4 cm.	1.8-2.0 cm.

In the Alpine regions, therefore, the plant was only $\frac{1}{3}$ or $\frac{1}{4}$ as high and the leaves only $\frac{1}{3}$ — $\frac{1}{4}$ as large as in Vienna, whilst the flowers in the Alpine region had a much smaller diameter than in Vienna.

Comparing the hermaphrodite plants of *Lychnis Viscaria* in the experimental garden of the Blaser with those of the same species at Vienna, we obtain the following:—

	Vienna Botanic Garden.	Experimental Garden on the Blaser.
Height of the stem, including } the axis of the inflorescence }	400-500 mm.	230-240 mm.
Dimensions of lower leaves	80 mm. long, 4 mm. broad.	50 mm. long, 3 mm. broad.
Inflorescence	80 " " 50 " "	60 " " 40 " "
Calyx	15 " " 6.5 " "	13.5 " " 5 " "
Lamina of petals	10 " " 8 " "	8 " " 6.8 " "
Claw of petals	8 mm. long.	7 mm. long.

Plants from the Alpine garden, therefore, when compared with those from the Vienna Botanic Garden, exhibit smaller measurements of stem, leaves, and flowers. The following points were also noted: the number of internodes in plants from the Vienna Garden was 9, of which 5 were on the axis of the inflorescence; each cyme consisted of 3-5 flowers, and the whole inflorescence bore 33-40 flowers. Plants from the Alpine Garden had only 6-7 internodes, of which 3 belonged to the inflorescence; the cymes composing the inflorescence were only occasionally 3-flowered; in most of them only the central flower developed, the two lateral ones being suppressed. The whole inflorescence included only 5-11 flowers.

Plants of *Pyrethrum corymbosum*, from the Alpine Garden, compared with those from the Vienna Botanic Garden (all raised from one batch of seeds) showed the following differences:—

	Vienna Botanic Garden.	Experimental Garden on the Blaser.
Height of the stem	950 mm.	250 mm.
Dimensions of leaves	170 mm. long, 50 mm. broad.	45-50 mm. long, 20 mm. broad.
Diameter of the capitulum	26 mm.	20 mm.
Ray-florets	8 mm. long, 4 mm. broad.	7 mm. long, 3 mm. broad.

In this case, again, plants from the Alpine Garden, when compared with those of the Vienna Botanic Garden, had smaller stems, leaves, and flowers. The lobes of the foliage-leaves from the middle of the stem of plants from the Alpine Garden were pinnate, and the pinnæ were either entire or beset with two small teeth on each side, near the apex. The stem had ten foliage-leaves, the four uppermost of which were much reduced and served as scale-leaves for the lateral shoots arising from their axils. These lateral axes were not branched, and each bore only a single capitulum. There were five capitula altogether. On plants from the Vienna Botanic Garden the lobes of the foliage-leaves from the middle of the stem were more divided, and the pinnæ were beset on each side near the top with 3-5 teeth. The stem bore 25-27 foliage-leaves, of which the 6-8 upper ones were much reduced in size, and functioned as scale-leaves for the lateral shoots in their axils. These lateral shoots were branched, and each branch terminated in a caputular inflorescence. The total number of capitula was 20-30.

From these examples it will be seen that all the parts of plants grown in the Alpine experimental garden were much hindered in their growth. The foliage- and floral-leaves were smaller, the stems shorter, the number of internodes, foliage-leaves, inflorescences, and flowers was diminished. The flowers were relatively nearer the earth, and this was due not only to the diminished number and length of the internodes of the stem, but principally to the fact that the flowers sprang from the axils of the lower stem-leaves.

Plants growing in Alpine regions derive a great advantage from these alterations, which are chiefly produced during their development by the influence of the long and bright daylight of June, July, and August. If these plants had to produce the same under-structure as their fellows in the Vienna Botanic Garden, 2015 metres lower down, much time would be lost, and the earliest flowers would hardly open before October, at a time when the winter snow is already beginning to fall. But since the number of internodes is restricted, and flowers are developed from the lower stories, it is possible for the plants to blossom at the end of August and beginning of September, and perhaps to ripen their fruits—one of the chief aims of the plant's existence. To this modification in their mode of development is also due in part the repeatedly-mentioned fact that many alpine plants blossom earlier than those in lower regions. But in order to avoid misunderstanding, it must be expressly stated that in not one of the thirty-two perennial, nor in the biennial and annual species which blossomed in the Alpine experimental garden, was the early flowering hereditary; consequently these plants must be carefully distinguished from the so-called asyn-gamic species, which will be spoken of in one of the last chapters in this book.

The relation of light to the colouring matters of plants has been repeatedly the subject of careful investigation. All observers agree that the amount of the pigment known as anthocyanin increases and diminishes with the stronger or weaker sunlight enjoyed by the parts of the plant in question, and that the yellow colouring matter of flowers holds a similar relation. Chlorophyll, however,

is actually destroyed by bright light in plants which are not properly screened, and the green tissue is then blanched and assumes a yellow tint. Since the intensity of the sun's rays increases with the elevation in mountain districts (see vol. i. p. 525), we should expect that this effect of light would be shown particularly well in plants of high elevation. And this is certainly the case. The flowers of species grown in the Alpine garden on the Blaser at a height of 2195 metres above the sea exhibited, as a rule, brilliant floral tints, and some were decidedly darker than the flowers grown in the Vienna Botanic Garden. *Agrostemma Githago*, *Campanula pusilla*, *Dianthus inodorus (sylvestris)*, *Gypsophila repens*, *Lotus corniculatus*, *Saponaria ocymoides*, *Satureja hortensis*, *Taraxacum officinale*, *Vicia Cracca*, and *Vicia sepium* are good examples of this. Several species, which produced pure white petals in the Vienna gardens, e.g. *Libanotis montana*, had petals coloured reddish-violet by anthocyanin on their under sides in the Alpine garden. The glumes of all the Grasses which were green, or only just tinged with violet at a low level became a dark brownish-violet in the Alpine garden. The abundant formation of anthocyanin in the green tissue of the foliage-leaves and sepals, and in the stem, was particularly apparent. The leaves of the Stonecrops, *Sedum acre*, *album*, and *sexangulare* became purple-red, those of *Dracocephalum Ruyschianum* and *Leucanthemum vulgare* violet, those of *Lychnis Viscaria* and *Satureja hortensis* a brownish-red, and the foliage-leaves of *Bergenia crassifolia* and *Potentilla Tirolensis*, even in August, had the scarlet-red colour which they usually assume in sunny spots in the valley in late autumn. I must not omit to mention that, according to some of my zoological friends, many animals, especially spiders and snails, which have been transferred from the plains to the mountain-heights, assume a darker tint in alpine regions.

A considerable number of plant species, especially those which grow in the valley in shaded or half-shaded places, as, for example, *Arabis procurrens*, *Digitalis ochroleuca*, *Geum urbanum*, *Orobis vernus*, *Valeriana Phu*, and *V. simplicifolia*, *Viola cucullata*, developed more or less yellowish leaves in the Alpine garden, where they were exposed to the full sunlight. It was mentioned in vol. i. p. 393, that the Flax (*Linum usitatissimum*), which flourishes in mountain valleys at a height of 1500 metres, where its chlorophyll is uninjured, nevertheless turns yellow in the Alpine garden at a height of 2195 metres.

From this general review of the modifications in plant-form obtained by culture-experiments, a series of important conclusions may naturally be drawn. In the first place we must point out that two kinds of characters are to be observed in plants, those which are the result of certain conditions and properties of soil and climate, and those which appear independently of these external influences. This distinction is so important that we shall illustrate it by two examples. The white Water-lily, *Nymphaea alba*, develops scale-leaves of ovate or lanceolate shape with no separation into petiole and lamina. The foliage-leaves, however,

have a rounded petiole and a disc-shaped lamina. These characters are always present whether the seed which produced the plant germinates in a deep lake or in the mud of a marshy meadow. In the marshy meadow the scale-leaves remain short, and the walls of their epidermal cells thicken in a remarkable way; the petioles of the aërial foliage-leaves become about a span long, and, in order to increase their resistance to bending, a strong layer of bast arises, the thickness of these bast-layers amounting to 0.17 mm. The walls of the epidermal cells are thickened, 5-9 layers of collenchymatous cells are formed under the epidermis with walls 0.07 mm. thick, and the air-spaces in the centre of the leaf-stalk are much narrowed. But if this species of Water-lily grows under water, the scale-leaves elongate into long and flaccid ribbons, and the petioles of the foliage-leaves continue to grow until their blades are raised to the surface of the water. According to its depth they attain a length of 30, 40, 50-100 cm. Resistance to bending is but little required by the petioles, which are surrounded by water, and the bast is therefore only slightly developed. The strings of bast which traverse the leaf-stalk are only 0.11 mm. thick, the walls of the epidermal cells are only half as thick as in the aërial leaves, only 3-5 layers of collenchyma are developed below the epidermis and the air-spaces in the centre of the leaf-stalk have a diameter of over half a millimetre. These petioles are consequently flexible, and cannot support the leaf-blade if taken out of the water. The general form of the scale- and foliage-leaves, the segmentation of the latter into petiole and blade, the configuration of the blade and the distribution of the bundles in it are all the result of internal forces due to the specific constitution of the protoplasm; but the thickness of the epidermal cells, the strength of the mechanical tissue, and the length of the leaf-stalk, are determined by the depth of the water-covering. The same thing is seen in the flowers; their structure depends upon the specific constitution of the protoplasm, but the size of the petals is determined by the temperature of the water.

The Meadow-grass *Poa annua* has a rapid growth; its haulms and leaf-sheaths are round, the leaf-lamina is traversed by seven strands, the lower branches of the inflorescence are single or paired but never whorled, and the spikelets of the panicle are much compressed and egg-shaped in outline. These characters are unalterable and are observed in *Poa annua* under all conditions. But when the haulms growing in the gardens in the plain project beyond the short upmost leaf the spikelets become 6-7-flowered, and have a pale green colour. When the plants become perennial in alpine regions the haulms bend towards the ground and remain so short that they do not reach above the highest foliage-leaf; the spikelets develop only 3-4 flowers, and their glumes are dark violet on the surface and brownish-yellow at the edge; thus these modifications are in relation to peculiarities of situation (in the plain and alpine regions) as effect to cause, and are to be ascribed to the influences of heat, light, and moisture, which act in various ways according to the situation.

These alterations are always to the advantage of the plant. They make the

individual more resistant, support and protect its organs, and render it possible for the separate parts to perform their work in spite of the necessarily altered conditions. They seem to have the task of keeping the plant alive under very different vital conditions, of promoting growth and the formation of offshoots and fruit with the smallest possible expenditure, and they may therefore be regarded as adaptations to the particular conditions of soil and climate.

The capacity for adaptation is of course founded in the specific constitution of the protoplasm, and is very different in different species. One species may adapt itself by appropriate alterations to the influence of bright light, submersion under water, a dry atmosphere, &c., while another cannot do so. If the protoplasm of the Flax (*Linum usitatissimum*) could manufacture as much anthocyanin in its green tissue as the Summer Savory (*Satureja hortensis*) it would blossom and ripen its fruits in alpine regions as this plant does, and would not succumb to the effect of the strong light. If the protoplasm of the Common Bent-grass (*Agrostis vulgaris*) were able to continue its constructive activity under water it would not perish as soon as it is submerged, but would maintain itself like the stoloniferous species (*Agrostis stolonifera*) by green stalks and leaves adapted to an aquatic habitat. In short, the adaptability of each species is restricted within definite limits which depend upon the specific constitution of the protoplasm and cannot be overstepped.

It is a matter of great import in the history of species whether modifications in form effected by change of soil and climate are transmitted to the descendants, and whether they can be inherited. This of course can only be ascertained by experiments, and by experiments in which all possible sources of error have been eliminated. This last remark is made advisedly, for the sources of error in such experiments are very numerous. I will briefly indicate two which interfered with some experiments I carried out in the years 1863 and 1864. It is not enough to be careful that the seeds sown in the prepared experimental beds are all from the same plant; care must also be taken to see that they are not the result of a hybrid cross-fertilization. Some seeds taken in 1863 from a plant of *Dianthus alpinus* growing in the Botanic Garden at Innsbruck, and sown in different soil in two experimental beds, produced plants in soil free from lime, which, in their external appearance, agreed with *Dianthus deltoides*. It seemed as if *Dianthus alpinus*, a lover of limestone rock, had become transformed into *Dianthus deltoides* when grown without lime. The seeds of the plant so like *Dianthus deltoides* were again sown in soil without lime, but the resulting plants no longer resembled this species; they showed themselves to be constant in their characteristics. The whole experiment with *Dianthus alpinus* was then repeated, but this time the plants on the clay soil without lime did not change, and I was obliged to conclude that the plant I had regarded as a stage in the transformation of *Dianthus alpinus* into *Dianthus deltoides* was a hybrid of these two species. In order to be certain about this a crossing between the two species was effected artificially. From the resulting seed plants were actually grown which were exactly like those I had regarded as transformations, and there was no longer any doubt that some of the

stigmas of the *Dianthus alpinus* which had yielded the seeds for the first experiment had been pollinated by insects with the pollen of *Dianthus deltoides*.

Mistakes often arise also from the fact that the young stages of many plants are very different from the fully-grown specimens. Young Birches grown from the seeds of *Betula verrucosa* bear leaves which are simply serrated, thickly covered with hairs, and soft to the touch. They are deceptively like the leaves of adult plants of *Betula alba* or *pubescens*. The leaves of the adult *Betula verrucosa* have quite a different form; they are doubly serrated, smooth, and harsh to the touch. These latter are the only form of leaf described in Botanical books for *Betula verrucosa*. Anyone sowing the seeds from a grown tree, and watching them grow up, with leaves of a different shape and surface, might easily think an actual fundamental change had occurred, and might be tempted to regard the transformation as the direct effect of a change in external influences.

It is perhaps superfluous to state that due regard was paid to these possible sources of error in the later series of cultural experiments, carried out during six years in the Alpine garden on the Blaser (2195 metres), and for comparison in my Villa Marilaun in the high-lying Tyrolese Gschnitzthal (1215 metres), in the Botanic Garden at Innsbruck (569 metres), and in the Botanic Garden of the Vienna University (180 metres); *in no instance was any permanent or hereditary modification in form or colour observed.*

Seeds of a plant grown in the valley when sown in the Alpine region produced plants which exhibited the modifications described above. They were also manifested by the descendants of these plants *but only as long as they grew in the same place as their parents*. As soon as the seeds formed in the Alpine region were again sown in the beds of the Innsbruck or Vienna Botanic Gardens the plants raised from them immediately resumed the form and colour usual to that position. The modifications of form and colour produced by change of soil and climate are therefore not retained in the descendants; the characteristics which appear as the expression of these changes are not permanent, and the individuals are to be therefore regarded as varieties, of which Linnæus says in his *Philosophia Botanica*: "Varietates tot sunt, quot differentes plantæ ex ejusdem speciei semine sunt productæ. Varietas est Planta mutata a caussa accidentali: *Climate, Solo, Calore, Ventis, &c.*, reducitur itaque in *Solo* mutato."

THE INFLUENCE OF MUTILATION ON THE FORM OF PLANTS.

When Birches and Firs grow up side by side in a wood-clearing, the crowns of the Birches will overtop the Firs in some twenty years' time, and this will seriously interfere with the growth of the latter. With every blast of wind the whip-like branches of the Birch strike against the upper shoots of the Firs, so that these gradually wither and die off. A lateral branch of a Fir tree altering its direction of growth and replacing the dead leader will, in its turn, soon be scourged to death. The top of the Fir is permanently mutilated, and the injury

can be recognized years after by the flattened form of the crown, so different from the usual appearance, when the offending Birches have perhaps long disappeared. Many other trees wage the same war with one another, the result in each case being the mutilation and alteration of the form of the summit of one of the trees. The Maple, for example, is either put quite *hors de combat* by the long thorny branches of a neighbouring Gleditschia (*Gleditschia triacanthos*) or else the crown becomes lop-sided owing to the destruction of the branches on the side facing the Gleditschia.

The way in which the appearance of Firs, Larches, Beeches, and Ling is altered by the attacks of ruminants, especially goats, was described in vol. i. p. 445, and we may add here that Pines and Junipers are mutilated in the same manner. The consequence is that lateral branches, which would not otherwise develop, grow out in the following year from the base of the twigs which have been bitten off. Apparently no other alteration takes place in these plants. But when huge boughs are broken off close to the ground by storms and the weight of snow, when the tree-trunks of the forest are sacrificed to the wood-cutter's hatchet, and the stems of seedling trees and shrubs in the meadow to the mower's scythe, when all the young shoots are frozen by a night's frost in spring, or when all the leaves are devoured by caterpillars and the branches are left bare as in winter—then the consequences are much more serious. In these cases new shoots make their appearance either from "eyes" in the stem or from the reserve-buds of the branches and twigs, or by buds produced by the roots below the ground. The leaves of these shoots, or *suckers*, as they are called, differ very much from those of the branches which have been broken, eaten, cut, or frozen off. The leaves from the crown of the Aspen (*Populus tremula*) are stiff and smooth in their adult condition; the circular blade is borne on a long petiole, and its margin is coarsely notched and undulated. The lateral veins traversing the blade are lost in a network near the edge in which no strong curved ribs occur. The leaves of a sucker from the base of a mutilated stem, or from the root, are soft and thickly covered on both sides with downy hairs; the heart-shaped blade is borne on a short stalk, and the margin is beset with numerous upwardly-directed notched teeth. The lateral veins of the blade merge near the edge of the leaf into a network, in which strong curved ribs are plainly visible. The leaves from the crown of the Oak (*Quercus pedunculata*) are deeply lobed and furnished with two so-called auricles at the base; those of the suckers are quite entire or very slightly lobed, with no auricles at the base. The leaves of the sucker of the common Beech (*Fagus sylvatica*) are more or less plainly serrated at the edge, while those of the topmost branches of the tree are quite entire. In the Black Mulberry (*Morus nigra*), and in the Paper Mulberry (*Broussonetia papyrifera*), the leaves of the sucker have a sinuous margin and are more or less deeply lobed, but those of the tree-top are heart-shaped with notched margins and no lobes. The leaves of the sucker of the Birch (*Betula verrucosa*) are simply serrated, with velvety hairs; those on the crown of the tree are doubly serrated and

smooth. The leaves on the suckers of the Round-eared Willow (*Salix aurita*) are broadly ovate, fairly smooth, and the veins in the blade form a wide-meshed reticulum; the leaves on non-mutilated branches are widened in the upper third, strongly wrinkled, and covered with grey hairs, whilst the reticulum of the veins is narrow-meshed. In *Salix rosmarinifolia*, the leaves of the suckers are twice or three times as broad as those of the normal branches, and they are smooth, while those of ordinary branches are covered with silky hairs, and gleam like silver. Hundreds of trees and shrubs might be mentioned in which there is a distinct difference between the foliage of the suckers and of the normal branches of the crown. But these few examples will suffice, and we will only mention the Norway Maple (*Acer platanoides*), because the difference in the foliage-leaves can be seen from the illustrations in vol. i. The leaves of the summit (see vol. i. fig. 106, p. 416, and fig. 109, p. 419) are borne on long petioles, the blade is 5-7 lobed, and the lobes are short and beset with several pointed, tapering teeth. The leaves of the suckers in this same Norway Maple are short-stalked, the blade is slightly 3-lobed, and each lobe is triangular and without the elongated pointed teeth. They exactly resemble the first foliage-leaves shown in vol. i. p. 9, fig. 1^a. This is also true of the leaves on the suckers of other woody plants. The shoots developed from reserve buds, "eyes", and the like, repeat to a certain extent the beginning of the leafy stem, so that the phenomenon is only an exhibition of the usual metamorphosis of the foliage-leaves. The difference between the older and younger, i.e. lower and upper foliage-leaves, only seems strange because the two kinds of leaf-forms are not usually seen simultaneously on one and the same plant. By the time the crown of a tree has developed, the first (oldest) leaves which adorned the young sapling have long disappeared. Many descriptive Botanists, as a rule, only consider the foliage-leaves of the fully-grown trees and bushes; some of them have hardly ever seen the first leaves of the commonest trees, and when they do happen to come across them they regard them as an extraordinary phenomenon, declare the shoots bearing them to be "bud variations", and draw bold and bewildering hypotheses from their appearance. This alteration in form, however, has nothing to do with the formation of varieties, nor is it dependent either upon the influence of the soil or upon the effect of climate. Moreover, the form of leaf characteristic of the sucker is not possessed by the secondary shoots which arise from the suckers; these are adorned with the same foliage which occurs on the topmost branches of the tree.

Alterations in the scale-leaves as well as in the foliage are brought about by mutilation of the branches. When the upper portions of Willow boughs with their foliage-buds are cut off, leaving the lower portions with the buds of the flower-catkins on them, the small pale scales at the base of the catkins change into green foliage-leaves; the axis bearing these leaves elongates, and the catkins then form the termination of a leafy shoot. Many Willows, e.g. *Salix cinerea* and *S. grandifolia*, by this metamorphosis assume a very unusual appearance. In the following year the branches bearing the flower-catkins, if they are

not mutilated afresh, will again put out short catkin-stalks with small pale scales.

Mutilation of herbaceous plants is caused by herbivorous animals, viz. insects and mammals, and on a large scale by man when he mows the meadows and cuts the crops and makes other necessary invasions on the natural vegetation in the interests of husbandry. The alterations caused by these mutilations of the foliage-leaf region are in the main the same as in woody plants. From the remaining stumps of the stem lateral shoots arise whose first leaves are like the first leaves of the seedling. Usually they are less divided and have fewer hairs than the leaves on shoots of normal plants, and on this account they have a very different character. In the floral region the effects of mutilation are twofold—first the peduncles or the lateral axes which are terminated by inflorescences elongate, and then the flowers become smaller. For example, when a vigorous stalk of the Ox-eye Daisy (*Chrysanthemum Leucanthemum*) bearing a capitulum is cut off close to the ground, long lank lateral stems develop from the axils of the lowest remaining leaves, each one ending in a capitulum. The main stem is now seen to be branched at its base, which is never the case in normal plants. If about half the stalk of the common Foxglove is cut off in the spring long flower-racemes will arise from the axils of the leaves just below the cut, but the flowers will be only half as large as those which would have developed on the uncut main stem. The stem of *Althæa pallida* rises a metre above the ground if its development is not hindered, and forms fascicles of short-stalked flowers in the axils of the upper leaves. If the stem is broken off lateral axes develop from the axils of the remaining leaves, and bear little long-stalked flowers. Particularly good examples are furnished by the annual weeds *Delphinium Ajacis*, *Nigella arvensis*, *Stellera Passerina*, and the like, which grow up amongst cereals. Their main stems are broken off when the corn is cut, and they then develop comparatively long branches with small flowers from the remaining stumps. If only single flower-buds, and not the whole inflorescences, are removed from a herbaceous plant whose main stem terminates in a long raceme, so that each flower is cut away in turn from below upwards just before it opens, the rachis of the raceme elongates enormously and flower-buds are developed at its end which would certainly not have unfolded had there been no mutilation. In the Red Foxglove, for example, the rachis of the raceme which has been damaged in this way will grow to twice its ordinary length, and twice as many flowers will be developed. The last and highest flowers in such racemes, however, are only half the size of those which arise on normal racemes.

We must now consider certain perennial meadow plants which when mown down are stimulated by the mutilation to develop flower-stalks in the same year, which would, in the normal course of things, not have flowered till the year following. In Alpine valleys it is a very common thing for the flowers of the spring plants *Anemone vernalis*, *Geranium sylvaticum*, *Gentiana verna*, *Polygonum Bistorta*, *Primula elatior* and *P. farinosa*, *Trollius Europæus*, &c., to appear in

the autumn in meadows which have been mown in the spring. The flowers appearing under these circumstances are remarkable for their small size. Their diameter is at least a third smaller than that of the spring flowers. In conclusion we may refer to the gardener's artifice which has already been described (p. 453) of producing perennial plants with woody stems from an annual Mignonette plant by mutilation. We might also mention the dwarf shrubs and trees produced by combined mutilation and grafting, especially the strange-looking little Ivy trees obtained by grafting a flowering branch of Ivy on an erect stem a span high, and the dwarf Conifers so much in favour with the Japanese.

Gardeners and descriptive Botanists have frequently determined and described mutilated plants as other species, hybrids, or varieties. They are neither the one nor the other. The peculiar appearance of the altered members resulting from mutilation is exactly determined beforehand in each species; it is due to the specific constitution of the species, and thus is part of its being. It is not produced by the external influences which lead to the formation of varieties, but is brought about by inherent necessity quite independent of the influences of climate and soil.

ALTERATION OF FORM BY PARASITIC FUNGI.

A considerable number of the trees and shrubs of Central and Southern Europe bear bristling, much-branched structures on some of their boughs which, from a distance, look like large birds' nests or brooms, and which have been popularly termed "witches' brooms". They are the outward and visible signs of a disease from which the plants in question suffer, and, as their name testifies, their origin was thought to be connected with witches. Traditionally witches have the power of "wishing" harm to mankind, animals, and plants; and superstitious people, at the sight of these peculiar pathological structures on the trees, may have started the idea that the disease was caused by witches that they might have brooms ready at hand for their midnight ride on the Brocken. Other plant diseases have been ascribed to unusual conditions of weather, especially to long-continued rain or great drought. It is not long since the discovery was made that most of the diseases attacking trees, shrubs, and herbs are caused by Fungi, and that atmospheric conditions are only concerned in the matter in so far as they hinder or favour the establishment and development of these parasites.

All the Fungi in question are parasites. They penetrate into the tissues of the host-plant and sooner or later cause the death of the affected part, and frequently of the entire host-plant. The living protoplasm in the cells and tissues of the host which is influenced by the parasite undergoes fundamental changes in its composition. Some of the cells are drained, their living protoplasm being consumed, so to speak, and these cells are obviously marked for destruction. Others are not killed, but changed. The metamorphosis occurs, in the first place, in the constitution of the living protoplasts which have not yet completed their development, the change much resembling that known as fermentation in fluid substances

(cf. vol. i. p. 508). In fermentation the chemical composition of the fluid is altered, its chemical compounds are shaken, decomposed, and split up and new compounds are formed by the action of the living Yeast cells. The same thing happens here in the interior of the living plant in its turgid, meristematic tissue—that is to say, in a group of protoplasts which still have the power of growing at the expense of materials supplied them, of increasing in size, and of multiplying by division. But these cells no longer behave as—in the absence of the parasite—they would have done. Profoundly modified under the influence of the parasite, but yet not killed, these cells, by their continued division, form tissues and organs of new and unusual form; in other words, that part of the host which is invaded but not killed by the parasite will continue to grow and increase in size, and in consequence of the change which its protoplasm has experienced will assume a different outward form.

These altered tissue-bodies produced by parasitic Fungi are called *gall-structures*. They are usually characterized by an excessive growth known as hypertrophy, as well as by their altered shape. The hypertrophy is without doubt caused by a stimulus proceeding from the parasite. We may conclude that the significance of the increased growth lies in the abundant supply of nourishment thus placed at the disposal of the parasite, since the large quantity of food-material brought for the excessive development of the hypertrophied growth connotes a large supply for consumption by the parasite. In many cases, however, the hypertrophied tissue merely forms a wall protecting the host against the further depredations of the intruder. It then contains no nourishment for the use of the parasite, being built up chiefly of corky cells, which the latter cannot consume or destroy. Such a tissue might be compared to the so-called callus which grows up in plants in parts deprived of epidermis after an injury, or in other wounds, and gradually covers them over with a protective layer.

The formation of the gall is often restricted to only a *small portion* of the afflicted plant; in other cases *whole leaves* and *branches*, and sometimes even *extensive shoots*, become modified in shape. To get a general idea of the four types of hypertrophied growths it will be best to take them one after the other in the order mentioned, commencing with the simplest.

The simplest of these galls consist of a few degenerate and metamorphosed cells in the centre of an extensive and unaltered tissue. They are produced chiefly by parasites of the genera *Rozella*, *Synchytrium*, *Exobasidium*, and *Gymnosporangium*. *Rozella septigena*, one of the Chytridiæ, develops swarm-spores which attack the various species of the fungal genus *Saprolegnia*. They settle on the tubular branches of the *Saprolegnia* at a place where it was just about to divide and to produce swarm-spores of its own. In consequence of the invasion of the parasite this does not take place, but the tubular cells which would have formed a *Saprolegnia*-sporangium divide instead into short barrel-shaped cells, each of which becomes a sporangium of *Rozella septigena*. In addition to this the infected cells develop lateral outpushings which swell up spherically, and each contains a resting-

spore of the parasite. Parasitic species of *Synchytrium* cause a vesicular enlargement of single cells of the epidermis in the leaves of phanerogamic host-plants. The not uncommon species *Synchytrium Anemones* and *S. Taraxaci* produce only a slight overarching, and the enlargement of the cells is hardly more than four times, often only twice the usual size. But, by the influence of *Synchytrium Myosotidis*, hypertrophied epidermal cells rise up from the leaves of the Forget-me-not (*Myosotis*) in the form of comparatively large, club-shaped, bottle-like, or egg-shaped bladders of golden or reddish yellow colour, and each contains the parasite, or rather its spores. The parts of the leaf attacked by *Synchytrium Myosotidis* are also much thickened, the palisade cells and the air-containing lacunæ of the spongy parenchyma (cf. vol. i. p. 279) disappear, and the tissue consists entirely of large similarly-shaped cells which fit close to one another, leaving no spaces between. In the gall caused by *Synchytrium pilificum* on *Potentilla Tormentilla* the much-enlarged cells in which the parasite settles are overgrown by the adjoining hypertrophied cells, some of which rise up in the form of hairs, and the whole new structure resembles a hairy wart.

A curious gall is produced by *Exobasidium Rhododendri* on a sharply-defined portion of the *foliage-leaves* of the Alpine Rose (*Rhododendron hirsutum* and *ferrugineum*). A spherical spongy body rises from a restricted portion of the leaf, usually from the under side of the somewhat projecting midrib, sometimes only as large as a pea, sometimes as big as a cherry, and occasionally even attaining the dimensions of a small apple. It is yellow, but rosy-cheeked like an apple on the side turned to the sunlight, and it reminds one of this fruit by its succulent tissue and sweet taste. Indeed, these galls are sometimes called "Alpine Rose-apples". Their surface is covered with a bloom which is caused by the numerous spores developed there and does not consist of wax like the bloom on an apple rind. The neck joining the gall to the leaf is not more than 1-2 mm. across, and, what is still more remarkable, except for this sharply-defined place of connection the infected leaf is unaltered.

Galls produced by the Gymnosporangia on the leaves of the Mountain Ash, Pear-tree, Rock-medlar, and other Pomeæ exhibit strange forms. One of them, caused by *Gymnosporangium conicum*, on the foliage of the Rock-medlar (*Aronia rotundifolia*), is represented in fig. 357². It resembles a tubercle furnished with horns projecting from the lower surface of the leaf. Microscopic examination shows that the knob consists of the strangely metamorphosed spongy parenchyma of the leaf. The intercèllular spaces which normally contain air are quite filled with the mycelial threads, and in the projecting portion of the tubercle, which is very hard and almost cartilaginous, tubes are inserted which terminate blindly below, where the spores of the parasite are developed, whilst above they are open and fringed, thus allowing the spores to escape. These tubes look like horns to the naked eye. Usually several galls occur together on the same leaf. They are conspicuous at some distance on account of their colour. The chlorophyll is destroyed wherever the mycelium of the parasite extends and a reddish-yellow

colour takes its place, so that orange spots appear on the surface of the foliage, contrasting vividly with the green of the unaltered portions of the leaf.

Galls rising from sharply defined parts of the *stem* are comparatively rare. One of the most remarkable is produced on the stems of a Laurel (*Laurus Canariensis*) by the parasitic *Exobasidium Lauri*. When it appears above the bark it looks like an aërial root, but rapidly grows into a branched spongy body 8–12 cm. long similar in appearance to one of the Fungi belonging to the family Clavariaceæ (cf. fig. 195¹, p. 21). The galls produced by *Entyloma Aschersonii* and *Magnusii* on the Composites *Helichrysum arenarium* and *Gnaphalium luteo-album*



Fig. 367.—Fungus-galls.

¹ Gall on the stem of the Juniper (*Juniperus communis*) produced by *Gymnosporangium clavariaforme*. ² Gall on the leaves of *Aronia rotundifolia* produced by *Gymnosporangium conicum*.

take the form of outgrowths, varying from the size of a pea to that of a walnut, developed from special spots on the root. Whether the spherical tubercles growing on the root-fibres of many Leguminosæ, especially those of the Bird's-foot Trefoil (*Lotus corniculatus*), the Fenugreek (*Trigonella fœnum-græcum*), Lady's-Fingers (*Anthyllis Vulneraria*), Lupin (*Lupinus variabilis*), and the Liquorice (*Glycyrrhiza glabra*) are to be regarded as true galls caused by the Bacteria-like organisms invariably to be found in their interior is questionable. According to the most recent investigations they are the outward expression of a case of symbiosis and not of pure parasitism.

Gall developments which involve whole roots or rootlets are found on the Alder (*Alnus glutinosa*), and on the Cabbage (*Brassica oleracea*). The gall which is produced on Alder roots by *Frankia Alni* attains the size of a walnut and has a

curious gnarled appearance; all the fibres of the root-branch thicken in a club-like or tuberous manner and become twisted and entangled with one another. The so-called "Fingers and Toes", caused by the Myxomycete (*Plasmodiophora Brassicæ*), is a gall-like hypertrophy on the root of *Brassica oleracea*, which not uncommonly grows to the size of a man's head.

Many woody plants have galls which alter the internal structure as well as the outward appearance of large tracts of the stem. The parasites settle in the cortical parenchyma, producing hypertrophy there, and afterwards the most varied distortions and alterations in the wood of that region of the stem. The trunk, branch, or twig becomes much swollen or knotted and the cortex rent and torn. Resin or a gummy mucilage sometimes runs out of the rifts in the gall. As such a parasite exercises its metamorphosing faculty for several years, the canker (as it may be termed) increases in size continually. Sporangia of varied form and colour appear annually on the affected places, and again disappear when they have shed their spores. The part of the stem or branch above the cankerous cushion dwindles and dies off sooner or later. It rarely happens that the tree or shrub is able to rid itself of the parasite. Occasionally a growth of wood and cork from the adjoining healthy part walls in the cankerous spot so that the parasite is destroyed. The gall produced by *Gymnosporangium clavariæforme* on the trunks and branches of the common Juniper (*Juniperus communis*) is an example of this form (see fig. 357¹). From the hypertrophy there project in the early spring golden-yellow tongues (shown in the figure) consisting of masses of spores embedded in mucilage. Other similar growths are produced on species of Juniper by *Gymnosporangium conicum*, *G. Sabinae*, and *G. tremelloides*, but it would take too long to describe their differences in detail. It is important to mention, however, that each of these parasites has two stages of development, living on different hosts, the hypertrophies as well as the associated spore-producing organs of the parasite being different in the two cases. The "Æcidium stage" produces cartilaginous swellings (see p. 520) in definite spots on the foliage of various Pomeæ (*Aronia*, *Cratægus*, *Pyrus*, *Sorbus*), the "Teleutospore stage" thickenings and tuberous outgrowths on the trunks of Junipers (*Juniperus communis*, *excelsa*, *Sabina*), and these parasites can travel from one host to the other in turn. (The two stages on different hosts are shown in fig. 357; these are not of the same fungus, but of nearly allied ones, and illustrate the point mentioned.)

The parasite *Peziza Willkommii* attacks the trunks and branches of the Larch (*Larix Europæa*), and produces the well-known Larch-disease or "Larch-canker". The parasite having gained access at some point on the stem or branch first penetrates the cortical parenchyma, and affects the cambium so as to prevent the further development of wood in that place. The development of the wood on the opposite side of the stem, i.e. the formation of annual rings, may proceed for several years, and in this way the attacked spot on the trunk takes the form of a depression, which is rendered the more conspicuous should the wood and cortex surrounding the parasite have undergone a greater thickening than usual. In

time the patch becomes a sunken, blistered hole from which resin flows; and every year the fructifications appear above the cortex in the form of numerous little cup-like structures which are white outside and scarlet-red in the concavity. As the disease progresses the infected patch gradually spreads, and infected trunks and branches can be easily distinguished at a distance. Towards the end of summer the needles on the twigs above the canker turn yellow, while those on the healthy branches are still a beautiful green. This premature discoloration is a sure sign of the speedy death of the whole bough. A similar canker is produced on the

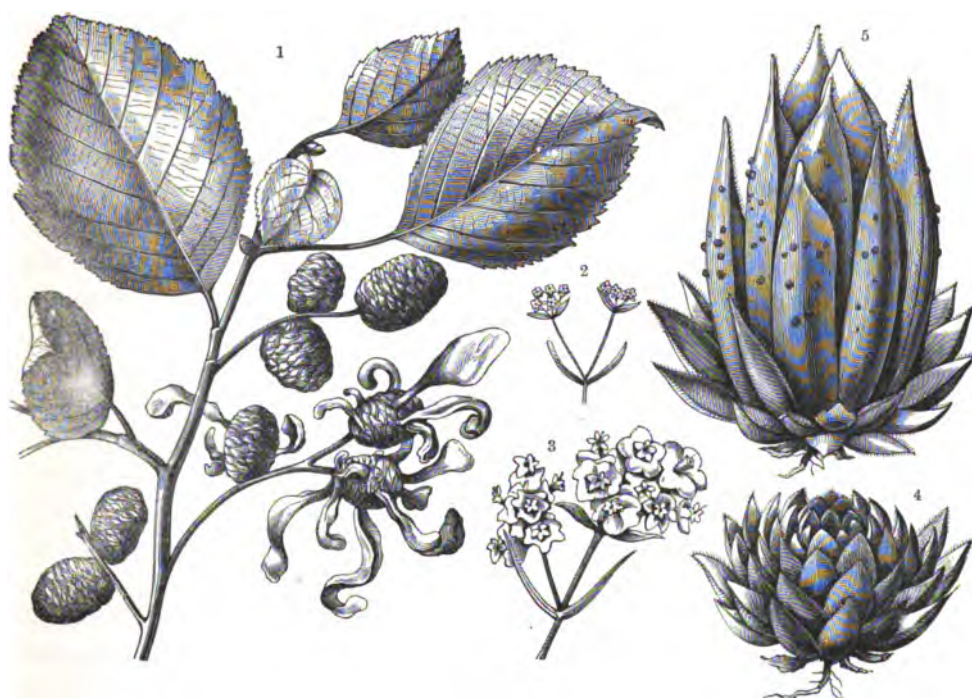


Fig. 358.—Various Galls.

¹ Gall on the bract-scales of the pistillate flowers of the Gray Alder (*Alnus incana*) produced by *Exoascus Alni-incanae*.
² Inflorescence of *Valerianella carinata*. ³ The same inflorescence with galls produced by a gall-mite. ⁴ Leaf rosette of the House-leek (*Sempervivum hirtum*). ⁵ Leaf rosette of the same plant which has been attacked by the fungus *Endophyllum Sempervivi* and has become hypertrophied.

Silver Fir (*Abies pectinata*) by *Aecidium elatinum*, but instead of being only on one side of the branch, as in the Larch, it forms a uniform swelling all round it. Cankers of this kind are produced by a Bacterial organism (*Bacillus amylovorus*) on fruit-trees (Apple, Pear, &c.), and on various trees belonging to the Amentiferæ (Beeches, Hornbeams, Oaks, &c.) by the Fungus *Nectria ditissima*.

When *whole leaves* undergo hypertrophy of the kind we have particularly remarkable changes of form. For example, the normal leaves forming the rosettes of the House-leek (*Sempervivum hirtum*; see fig. 358⁴) are broadly obovate in form, being little more than twice as long as they are broad. The leaves of the same plant after they have been attacked by the parasitic *Endophyllum Sempervivi*

vivi (see fig. 358⁵) are seven times as long as broad and linear in shape. They stand erect, and are of a much paler colour than the healthy leaves. The Wood Anemone (*Anemone nemorosa*) affords another example (see fig. 259, p. 229). It spreads by creeping stems under the surface of the ground, and forms small colonies in light thickets and in meadows. The plants consist partly of flowering lateral shoots, and partly of foliage-leaves, which emerge above the ground from the creeping underground stem. In normal leaves the erect petioles are all the same length, and the leaflets are extended at about the same level. But when the *Æcidium* stage of *Puccinia fusca* has settled on them this becomes altered. The blades of the infected leaves tower over their healthy neighbours in consequence of the elongation of their petioles, whilst their leaflets are smaller and less divided. The length of the petiole in normal leaves is some 12–13 cm., in hypertrophied leaves 15–18 cm.; but the size of the altered segments, compared with those of normal leaves, is as 5:7. Similar changes are observed in leaves of *Soldanella alpina* when attacked by *Puccinia Soldanellæ*. The petioles of the infected leaves are 2–4 times as long as the normal ones, the blade is smaller and hollowed like a spoon instead of being flat, and the colour is an ochreous yellow instead of a dark green. The same alterations in the length of the petiole, and in the size and colouring of the leaf-lamina, are produced in the leaves of *Alchemilla vulgaris* by *Uromyces Alchemillæ* and in those of *Phyteuma orbiculare* by *Uromyces Phyteumatum*. To this class belongs also the so-called "curl" disease of Peach and Almond trees, produced by *Exoascus deformans*, and rendered conspicuous by the considerable enlargement, undulation, and bladder-like expansion of the infected leaf-surface, which acquires generally a very brilliant coloration.

Floral-leaves are comparatively seldom metamorphosed by Fungal parasites. In the Alder (*Alnus glutinosa* and *incana*) the bracts of the pistillate flowers are changed by *Exoascus Alni-incanæ* (= *E. amentorum*) into elongated purple-red spatulate lobes much twisted and bent (see fig. 358¹); *Peronospora violacea* sometimes causes the stamens to change into petal-like structures in the flowers of *Knautia arvensis*, so that they then seem to be "double"; *Ustilago Maydis* causes a growth of tissue in the pistillate flowers of the Maize, the result being that instead of grains irregular cushion-like structures 7 cm. in diameter are produced. *Taphrina aurea*, which settles on the pistillate flowers of Poplar (*Populus alba* and *tremula*) causes the ovaries to form golden-yellow capsules more than twice the usual size. The galls produced by *Exoascus Pruni* on the ovaries of wild Plum, Bullace, Sloe, and Bird Cherry (*Prunus domestica*, *insititia*, *spinosa*, *Padus*) belong also to this class. The tissue of the ovary increases in size, but not in the same way as in fruit formation. The resulting body is flattened on two sides, brittle and yellow; the seed inside is abortive, and a hollow space is left in its stead. The gall produced from the ovary of *Prunus domestica* has the form of a rather curved pocket, which looks as if it had been powdered outside with flour at the time the spores ripen. These hypertrophies, which are popularly termed "pocket-plums", "bladder-plums".

&c., fall off the trees at the end of May. They are eaten in many districts, but have an insipid, sweetish taste.

Galls consisting of *whole shoots*, both the stem and its leaves being altered by the parasite, are found principally on trees and shrubs, and only rarely on herbaceous plants. Examples of the latter, however, are furnished by the metamorphosed shoots of the Shepherd's Purse (*Capsella Bursa-pastoris*) produced by *Cystopus candidus* and *Peronospora parasitica*. Here the leaves, especially the floral-leaves, as well as the ground-tissue of the stem undergo pronounced hypertrophy. The petals, which measure only 2 mm. in length in a healthy plant, may become even 15 mm. long; the sepals also elongate, become fleshy and brittle, and are distorted and crumpled in all manner of ways. Only six stamens are developed in normal flowers, but in hypertrophied specimens there are often eight. The metamorphosis produced by *Uromyces Pisi* in one of the Spurges, *Euphorbia Cyparissias*, is even more remarkable. The stem elongates far beyond its usual dimensions, and the leaves, which are crowded together on normal shoots, are thus separated by considerable intervals. The distance between two adjoining successive leaves in the healthy *Euphorbia Cyparissias* is only 0.5 mm., but in the hypertrophied specimens it becomes 2-3 mm. Infected shoots on an average are twice as high as healthy ones. The foliage-leaves, which are thin, flexible, linear, and twelve times as long as they are broad in the healthy plant, become, in the infected specimens, thick, brittle, elliptical, and only 2-3 times as long as they are broad. The bluish-green colour of the normal plant is changed into a yellow-ochre tint, and this contributes not a little to the odd appearance of the plant. Affected plants are not uncommon in Switzerland; a locality in which this disease has been very prevalent in recent years being Saas-Fée in the Saas-thal. The metamorphoses produced on the shoots of Periwinkles (*Vinca herbacea*, *major*, and *minor*) by the Uredospore-stage of *Puccinia Vincæ* and on shoots of *Cirsium arvense* by the Teleutospore-stage of *Puccinia suaveolens* are very like those of the *Euphorbia* just mentioned, since the stem becomes much elongated and the leaves shorter, broader, yellow, and brittle. When flowers are developed on these affected shoots, they are more or less abortive and sickly, and no fruits or fertile seeds arise therefrom. Frequently the shoots blossom prematurely. For example, we can at once detect by its elongated rosette-leaves when *Primula Clusiana* and *minima* are infected by *Uromyces Primula integrifoliæ*, and it may be observed when this is the case that the shoots do not wait until the next spring to develop the flowers laid down in the summer, as usual, but open them in the autumn of the same year instead.

The Cowberry (*Vaccinium Vitis-Idææ*) is especially worthy of notice among low woody plants, because two kinds of parasite attack its shoots. *Melampsora Gæppertiana*, in the Teleutospore-stage, causes a marked, gouty thickening in the cortical parenchyma, which is converted into a spongy tissue; at first it is flesh-coloured, but soon assumes a chestnut-brown tint. The stems elongate very much and grow vertically upwards; and when several of them close together are thus attacked they present a besom-like appearance. The foliage-leaves are much

farther apart than in the healthy plant on account of this stretching of the stem. The lower leaves of the shoot are transformed into small fringed scales, and the upper ones are so much shortened that their outline becomes almost circular. The second parasite to which the Cowberry shoot is subject is *Exobasidium Vaccinii* (a near ally of the already mentioned *Exobasidium Lauri*, p. 521). The stem becomes pale rose-red colour, and rather thickened and spongy, but it does not elongate much more than usual; the leaves become blistered and curiously convex on the



Fig. 359.—A Witches' Broom on the Silver Fir, produced by *Aecidium alatinum*.

under surface. The substance of the infected leaves becomes brittle and loses its chlorophyll. A red tint appears in place of the green, especially on the upper surface of the leaf, whilst the lower surface, on which the spores develop, looks as if it had been dusted over with flour. Usually the buds develop prematurely on these shoots, *i.e.* the buds which, under ordinary circumstances, would not develop until the next year push out and form new shoots shortly after they have been laid down. The axes of these shoots, however, remain short; their leaves are closely crowded, red in colour, and sessile. From a distance the premature shoots look like large double red flowers inserted in the dark green of the non-infected Cowberry bush. The shoots which develop prematurely on the shrubs of the Bog Whortleberry (*Vaccinium uliginosum*) by the action of *Exobasidium Vaccinii* are often met with in alpine regions, and are even more noticeable on account of their fiery-red

colour. The Bearberry (*Arctostaphylos Uva-ursi*), *Ledum palustre*, and the Marsh Andromeda (*Andromeda polifolia*) are subject to similar metamorphoses at the hands of *Exobasidium Vaccinii*, so that *Vaccinium Vitis-Idæa* may be regarded as typical of them.

When the shoots of the larger shrubs or trees are metamorphosed by parasitic Fungi attacking their branches, we have the formation of the structures popularly termed Witches' brooms, which were mentioned at the beginning of this chapter. The stimulus necessary for their formation is afforded in different plants by different parasites; on Barberry bushes (*Berberis vulgaris*) by *Æcidium Magelhaenicum* (to be distinguished from the common *Æ. berberidis*), on the Gray Alder (*Alnus incana*) by *Exoascus epiphyllus*, on the Hornbeam (*Carpinus Betulus*) by *Exoascus Carpinii*, on the Bullace (*Prunus insititia*) by *Exoascus insititiæ*, on other species of the genus *Prunus* by *Exoascus Cerasi*, on the Birch (*Betula verrucosa*) by *Exoascus turgidus*, on the Weymouth Pine (*Pinus Strobus*) by *Peridermium Strobi*, and on the Silver Fir (*Abies pectinata*) by *Æcidium elatinum*. Witches' brooms also occur on the Mastic tree (*Pistacia Lentiscus*), and on Beeches, Pines, Larches, Spruce Firs, &c., although hitherto we have not been able to ascertain definitely what parasitic Fungi are the cause in these cases. The Witches' broom of the Silver Fir has been selected and figured (see fig. 359) as a type of these peculiar structures. It always grows on one of the horizontally projecting lateral branches of the Fir, and raises its erect or curved twigs from the upper side, resembling, as it were, an epiphyte growing on the bark of the horizontal bough. The twigs are grouped in whorls and not in two rows, as usually happens in the lateral shoots of the Silver Fir. They are all shortened and thickened, and remarkably soft and pliable, because the cortical parenchyma has become spongy and the wood is only slightly developed. The buds, which in healthy tissue are egg-shaped, are almost spherical here. As in other instances of hypertrophied plant-members, we have a precocious development, a so-called "prolepsis", in these Witches' brooms. The buds swell earlier and unfold earlier than those of healthy twigs. The leaves remain short, yellow, somewhat crumpled, and fall off when a year old, while those of normal twigs are long, linear, straight, dark green on the upper side, and remain in position from 6-8 years. The growth of the twig is restricted; it dies off in a few years, and then, inserted on the dark green branches of the Silver Fir, remain the dry, bristling brooms, whose appearance has stimulated the imagination of the peasantry and given rise to the superstitions alluded to at the beginning of this chapter.

ALTERATION OF FORM BY GALL-PRODUCING INSECTS.

Certain members of the Arachnoidea, Diptera, and Hymenoptera, which attack and penetrate the tissues of living plants and incite the formation of peculiar excrescences, are known as gall-mites, gall-gnats, and gall-wasps. The

growths, like small rosy-cheeked apples, which occur on the foliage of Oaks, popularly known as "oak-apples", are amongst the best known. The terms "gall" and "gall-apple" were used by writers in the sixteenth century, and (like the Old English word *galle*, the French *galle*, and the Italian *galla*) are derived from the Latin word *galla*, used for these outgrowths by Pliny in his Natural History. The sixteenth-century writers distinguish between "gall-nuts" and "gall-apples", meaning by the former the small hard outgrowths on the leaves of Beech-trees. Afterwards the word *gall* was used for all the outgrowths produced by animals on green living plants. More than that—the hypertrophies described in the preceding chapter, produced in green host-plants by the various families of Fungi, are also included under the term. It has been proposed recently to substitute the word *cecidium* for *gall*, and to distinguish the excrescences as myco-cecidia, nemato-cecidia, phyto-cecidia, diptero-cecidia, &c., according as they owe their origin to Fungi, Thread-worms (Nematodes), Gall-mites (*Phytoptus*), Gnats (*Diptera*), &c. A systematic classification of this sort, on the lines of the classification of animals, might be of use to Zoologists, but to the Botanist its value is only secondary. He must, as in other similar cases, keep to morphology as the primary ground of classification, and has to arrange the structures according to their agreement in development. Moreover, in a general review, it is necessary to consider whether a whole group of plant-organs or one alone undergoes metamorphosis; and the starting-point of the outgrowth must also be ascertained; *i.e.* whether it is the foliage-leaves, floral-leaves, stems, or root-structures, &c., which are the head-quarters of the excrescence.

When the gall originating as the nest or temporary habitation of a single animal or colony of animals is limited to a single plant organ it is said to be *simple*; if, on the other hand, several plant organs are concerned in its production it is said to be *compound*.

Simple galls may, for convenience of description, be divided into (1) *Felt-galls*, (2) *Mantle-galls*, and (3) *Solid galls*. The Felt-galls are chiefly due to hypertrophied epidermal cells growing out into hairy coverings of various sorts and shapes; Mantle and Solid galls, however, are rather more complicated. In both cases insects are present in swellings of various descriptions, but there is this essential distinction:—The Mantle-gall is a hollow structure which, though it may arise in various ways and assume a multiplicity of forms, always has a portion of the surface of the affected organ for its lining—in other words, it is a chamber formed by hypertrophied growth *around* the place occupied by the insect. In the Solid gall, on the other hand, some spot is *pierced* by an insect and the eggs deposited *in* the tissues (not on the surface), the punctured spot forms a swelling with the larva inside, but the lining of the chamber is in no sense a portion or development of the original surface of the organ affected. Again, whilst in most mantle-galls the cavity of the gall is in open communication with the outside, and the insect can escape by this aperture (though this is not invariably the case), in the solid gall there is not such opening, and the insect

has to bore its way out. Needless to say, of both these types there are numerous modifications, but they fall into the two classes (of mantle and solid galls) according to their mode of development.

The majority of *felt-galls* are produced by gall-mites. They form cottony or felted growths on limited and sharply defined areas of green leaves and stems, the surface of which is otherwise smooth, or possesses but few hairs. Sometimes they have the form of small tufts, bands, or stripes, sometimes of large spots with irregular contour. In most instances the felt is situated on the under side of the foliage-leaf, and the gall-mite usually prefers the projecting veins to the green surface. In the Lime, Alder, Hornbeam, and Horse-Chestnut, the mites usually establish themselves in the angles formed by the lateral strands where they arise from the midrib, the projecting veins forming the framework for the felted hairs. In the Bramble (*Rubus*) and the Burnet (*Poterium*) it sometimes happens that the felt is continued down from the lamina to the leaf-stalk, and occasionally the green cortex of the succulent twig is covered with felted bands and spots. In some Brambles and Cinquefoils the sepals become furred by the action of gall-mites, the usual consequence being that the outline also becomes distorted. A swelling or slight hollowing of the green leaf-tissue very frequently accompanies the formation of felted galls, in which case the hairy covering is only visible on the concave side whilst the other remains smooth. This is most remarkable in the foliage of the Avens (*Geum*), Vine (*Vitis*), and Walnut-tree (*Juglans*), where a dozen white or brown-felted pit-like depressions are sometimes to be seen on the under side of a single leaf. The colour of the felted hairs is white in the leaves of Beeches, Limes, Bird Cherry, Brambles, Cinquefoils and Burnets, green in the common Maple, yellow in the Spindle-tree (*Euonymus verrucosus*), sulphur-yellow in *Alnus orientalis* and Black Poplar (*Populus nigra*), carmine red at first and then violet in *Alnus viridis* and in the Birches (*Betula alba*, *carpatica*, &c.), and brown in the Avens (*Geum macrophyllum*), Horse-Chestnut (*Æsculus Hippocastanum*), and in the Aspen (*Populus tremula*). The felted galls which are light in their young stages usually take on a brown tint afterwards. Microscopic investigation has shown that in the formation of felted galls, the epidermal cells, originally tabular in shape and closely fitting, swell out and become transformed into bent and twisted tubes generally shaped like a club or retort, the stimulus being afforded by a minute gall-mite (*Phytoptus*). These cells look like short hairs to the naked eye, and as they stand side by side in large numbers the covering has a velvety or felted appearance. The mites which produce the felt, deposit their eggs in the juicy hair-shaped cells, and their young live on the materials contained in them. It should be mentioned that formerly these velvety and felted coverings were regarded as Fungi, and were described as distinct genera under the names *Erineum* and *Phyllerium* (e.g. the gall known as *Erineum quercinum* on the leaves of *Quercus Cerris*). To this group belongs also the gall occurring on the Wood Meadow Grass (*Poa nemoralis*) consisting of cells which resemble root-hairs, which is produced by the gnat *Hormo-*

myia Poæ. The hair-shaped cells are epidermal, and spring from the stem above the nodes; they break through the leaf-sheath which proceeds from the adjacent node, and are arranged in two groups, which grow in opposite directions, so as to wrap round the stem from the two sides. The whole hairy mass looks as if it had been parted into two. At first the hairs are white; later they become light brown, and when the gall is fully developed they have the form of brown felted strands, wound round the stems and firmly inclosing the larva of the gnat in question.

A large number of simple galls are grouped together under the name of *Mantle-galls*. The insects which give rise to them spend their lives on the surface of the leaves, where they multiply and attach their eggs to the epidermis. A growth is excited in certain layers of the cell-tissue by the stimulus which the animals exercise on their place of settlement. Cavities are thus formed which serve as dwellings for the animals and their brood, and which surround them like a protecting mantle. Mantle-galls may be divided according to their structure into *scroll*-, *pocket*-, and *covering-galls*. *Scroll-galls* are caused by gall-mites, leaf-lice, tree-hoppers, and flies, and usually occur on the blades, rarely on the petioles of the leaves. The surface inhabited by these animals, which, in the ordinary course of things would have spread out flatly, grows more luxuriantly on one side than on the other, and the result is the formation of a scroll, *i.e.* of a chamber in which the animals are hidden. It is always the side on which the animals live which becomes concave, and the leaf is usually curled up lengthwise. In the Alpine Rose (*Rhododendron*), Crane's-bill (*Geranium sanguineum*), and Orache (*Atriplex hastata*, *oblongifolia*, &c.), it is the upper side of the leaf which is tenanted by the insects, and is therefore the one to roll up; it is the lower side, however, in the Buckthorn (*Rhamnus cathartica*) and the non-climbing species of Honeysuckle (*Lonicera alpigena*, &c.). In many instances the whole leaf-lamina is rolled up, but more frequently the alteration is restricted to the edge of the leaf when the margin appears to be bordered with a swollen hollow cushion often corrugated or undulating. In the Alpine Rose (*Rhododendron ferrugineum* and *hirsutum*) both halves of the leaf-blade are rolled round (see figs. 360² and 360³), but usually the rolling is so slight that the gall has the form of a boat or hollow trough. Sometimes an alteration in the shape of the leaf accompanies the rolling. For example, the foliage of the Abele (*Populus alba*) on which *Pachypappa vesicalis* establishes itself when the leaves are very young, exhibits in addition to the rolling a deep hollowing of the blade. Instead of the short blunt lobes, long pointed segments are formed, which stand side by side when they are rolled up, and cross over one another in many ways so that the mantle-gall on the hollow side is shut in by a veritable lattice-work. The parts of the tissue brought into contact by the rolling do not fuse together, and therefore the cavity in which the gall-producing insects live is always in open communication with the exterior. In most cases the tissues concerned are thickened, brittle, more or less devoid of chlorophyll, and yellow in colour. Not infrequently a red pigment is formed in them, so that the outside of the gall has a yellowish-red colour. The scroll-gall produced by the hemipterous

Trioza Rhamni on the margin of Buckthorn (*Rhamnus cathartica*) leaves is very hard and thickened like cartilage. In many plants the epidermal cells lining the gall elongate into hairy structures, as in the felt-galls previously described. Their juicy contents are used as food by the young gall-mites. This is the case, for example, in the Alpine Rose (*Rhododendron ferrugineum*, cf. fig. 360³). *Pocket-galls* are closely allied to the scroll-like forms. The tissue of the leaf-lamina or

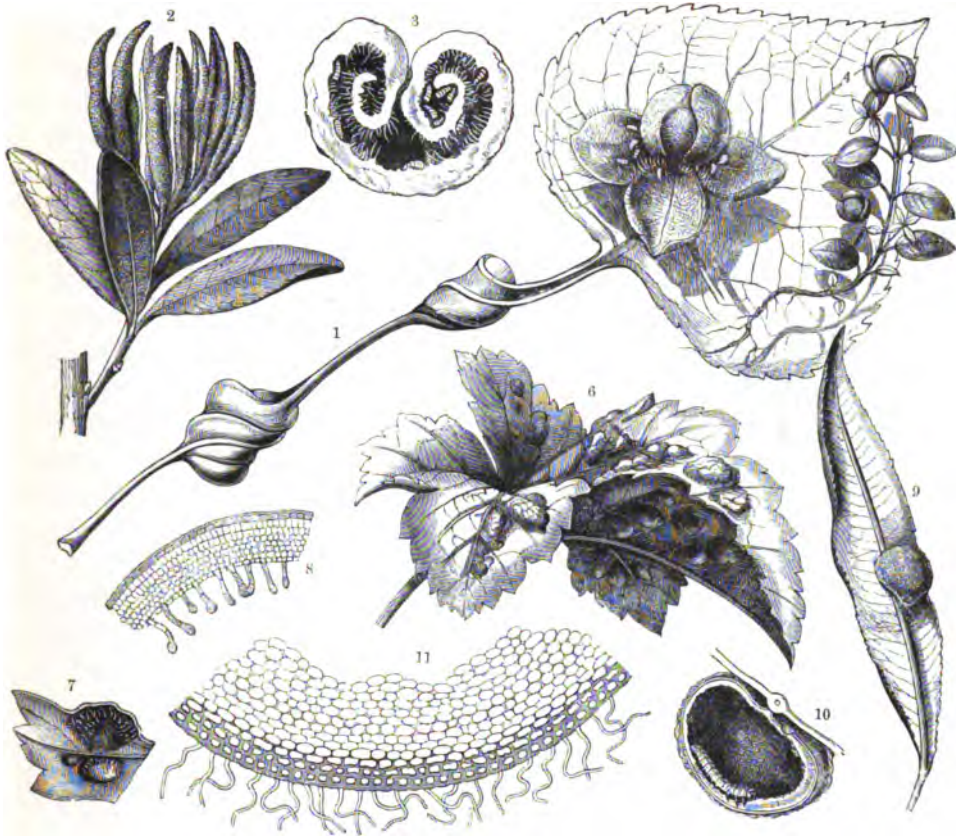


Fig. 360.—Galls.

¹ Covering-galls on the petiole of the Black Poplar (*Populus nigra*) produced by *Pemphigus spirotheca*. ² Scroll-galls on the leaves of an Alpine Rose (*Rhododendron ferrugineum*) produced by gall-mites. ³ Transverse section of one of these galls. ⁴ and ⁵ Bud-galls on the branchlets of the Wild Thyme (*Thymus Serpyllum*) produced by gall-mites. ⁶ Blister-like galls on the leaf of the Red Currant (*Ribes rubrum*) produced by *Myzus ribis*. ⁷ Part of the leaf seen from below. ⁸ Vertical section of a portion of this gall. ⁹ Solid gall on the leaf of the Gray Willow (*Salix incana*) produced by *Nematus pedunculæ*. ¹⁰ The same gall cut open. ¹¹ Part of the wall of this gall in vertical section. 1, 2, 4, 6, and 9 natural size; ³ and ⁵ $\times 4$; ⁷ and ⁸ $\times 8$; ¹¹ $\times 50$.

petiole and sometimes that of the cortex in young twigs is subjected to a stimulus where the animals (gall-mites, leaf-lice, diptera) settle, with the result that a hollow protuberance arises whose excavated cavity serves as a temporary dwelling for the insects. The protuberances exhibit a great variety of form and shape, and they differ considerably in their internal structure. The following are the most noticeable forms. First, the plaited galls. They form deep, plaited, sometimes twisted channels in the leaf-tissue which open on the upper side by a narrow hole, and

project like weals on the lower surface of the leaf. The growing tissue which forms the floor of the channel is yellow and often lined with short hairs. The channel usually follows the course of the larger veins of the lamina, and sometimes actually traverses one. Plaited galls are produced by gall-mites. The best known are those on the foliage of *Carpinus Betulus*, *Clematis Flammula* and *C. recta*, and *Ribes alpinum*. Wrinkled galls come next to the plaited form. The protuberance is here limited to the green tissue shut in by strong rib-like projecting veins, and is only shallow; the upper side of the leaf has bulgings and protuberances and the lower pits and cavities. The protuberances are always developed in numbers close together, so that the leaf looks very much wrinkled in that region. Examples of this form are furnished by the wrinkled galls on the Elm (*Ulmus campestris*; see fig. 361⁴) produced by the leaf-louse *Schizoneura Ulmi*, and on the Red Currant (*Ribes rubrum*; see figs. 360^{6, 7, 8}) by another leaf-louse, *Myzus ribis*. In the latter several wrinkles are usually united into large blister-like protuberances, red on the outside, and covered with jointed cellular structures bearing glands which look to the naked eye like short hairs. This form, though resembling certain felted galls, is distinguished from them by the different form of the hairs arising in consequence of the stimulation. In the Mouse-ear Hawkweed (*Hieracium Pilosella*) leaf-fleas (*Psyllodes*) produce minute protuberances with narrow mouths, which stand out from the lower side turned towards the ground like small warts, and when they occur close together give a corrugated appearance to the leaf. Hollow protuberances of this sort arising upon restricted areas of the leaf-surface, and growing very actively, give rise to bag or sack-like structures attached by a very narrow neck. From their resemblance to a head such galls are sometimes termed capitate galls (*Cephalonion*). In others, where the outgrowth is fairly thick-walled and in form horn-like, the designation horn gall (*Ceratonion*) has been given. Between these forms numerous intermediate forms exist which may be compared to pockets, bags, nails, &c. Many of these galls project from both the upper and lower side of the leaf, as though a nail had been driven through it—hence the last-mentioned name. The capitate-gall of the Sloe (*Prunus spinosa*), caused by a gall-mite, projects almost as much from the under as from the upper side, whilst the similar gall on the foliage of the Bird Cherry (*Prunus Padus*) rises on the upper side as a long pocket, but below only projects like a small wart. Many capitate and horn-like galls are developed only on one side, and here again there is a very great variety. When the protuberances are due to mites the cavity always opens on the lower side of the leaf. Both the inner wall and mouth of the cavity are covered with hairs, and sometimes the aperture seems to be actually plugged up by them. In the bag-shaped protuberances produced by the leaf-louse *Tetraneura Ulmi* on Elm leaves, a relatively large slit is formed just at the narrow part of the bag at the moment when the insects leave the cavity (see fig. 361⁵). The external surface of the protuberances caused by mites on the foliage of Alders (*Alnus*), Maples (*Acer*), and Limes (*Tilia*) is smooth, in those of the Bird Cherry (*Prunus Padus*),

and Wayfaring Tree (*Viburnum Lantana*) ciliated, whilst in the inflated galls of the Elm caused by the white woolly leaf-louse (*Schizoneura lanuginosa*), it is covered with fine hairs like velvet. The capitate galls on the foliage of Maples, Alders, and Limes, of the Guelder-rose and Strawberry, are scattered abundantly over the whole lamina; in the Sloe they stand out chiefly from the margin of the leaf, and in Elms they occur singly or in groups on its central portions. The size of these galls depends upon their distribution. Those which rise in hundreds from the



Fig. 361.—Galls.

1-3 Solid galls on a Rose-leaf; 1 of *Rhodites Rosæ*, 2 of *Rhodites Eglanteriæ*, 3 of *Rhodites spinosissimæ*. 4 Wrinkled galls on an Elm-leaf (*Ulmus campestris*) produced by *Schizoneura Ulmi*. 5 Purse galls on the same leaf, produced by *Tetraneura Ulmi*. 6 Covering gall on the same leaf, produced by *Tetraneura alba*. 7 Solid galls on the leaf of the Purple Willow (*Salix purpurea*), produced by *Nematus gallarum*. 8 Solid galls on the leaves of the same Willow, produced by *Nematus vesicator*.

same lamina have a diameter of 1-3 mm., while those which occur singly or in small groups, often attain a diameter of 2-3 cm.

Contrasting with these embossed or *pocket-galls* are the *covering galls*, forming a third type of mantle-gall. In these, as in the embossed forms, the insects producing the galls live in their cavities, but the course of development is quite different in the two cases. The tissue round the place where an animal has settled or where an egg has been fastened to the epidermis in this type begins to grow, rising up in the form of a fleshy mound or wall which continues to grow until the animal is wholly roofed in. The cavity in this case does not arise from an excavation (as in the embossed or "pocket" type), but from an overarching of the tissue. The

external appearance of these galls is very varied. One of the simplest forms occurs on the leaves of the Ash (*Fraxinus excelsior*, see fig. 362³), where it is produced by the gall-gnat *Diplosis botularia*. The insect having laid its eggs in the channelled depressions above the leaf-veins, fleshy cushions arise on either side of the groove which meet above and roof them over. The cushions of tissue forming the roof do not fuse; their succulent edges merely meet, and when the time comes for the gall-gnats to leave their temporary abode the tissue dries up and shrivels,

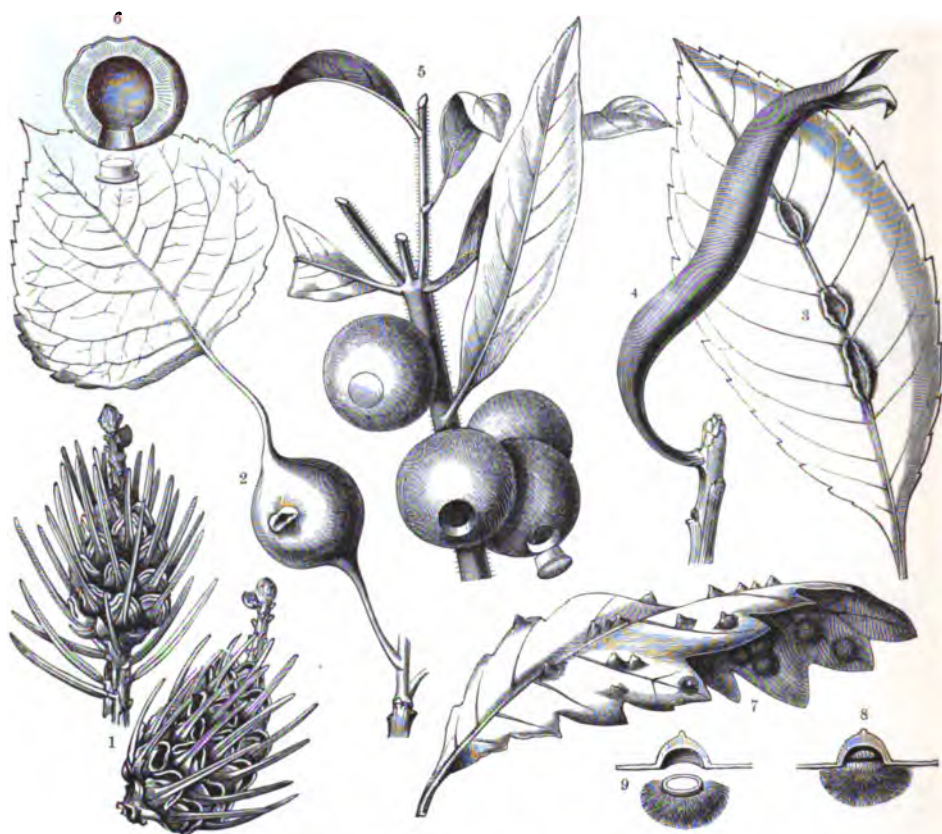


Fig. 362.—Galls.

¹ Pine-apple gall on twigs of the Spruce Fir produced by the Spruce-gall Aphis (*Chermes abietis*). ² Covering gall on the petiole of the pyramidal Poplar (*Populus pyramidalis*) produced by *Pemphigus bursaarius*. ³ Covering galls on an Ash leaf (*Fraxinus excelsior*) produced by *Diplosis botularia*. ⁴ Covering gall on Pistacia (*Pistacia Lentiscus*) produced by *Pemphigus cornicularius*. ⁵ Solid galls on the cortex of *Duvaua longifolia* produced by *Cecidoses Bremia*. ⁶ Longitudinal section of one of these galls. ⁷ Capsule galls on the leaf of the Turkey Oak (*Quercus Cerris*) produced by *Cecidomyia cerris*. ⁸ One of these galls cut through with the operculum: still firmly attached, and ⁹ the same with the operculum falling away; $\times 3$. The remaining figures natural size.

leaving a gaping slit as shown in fig. 362³. The same thing happens on the leaves or rather leaf-veins of the Stinging-nettle (*Urtica dioica*) and of the Alder (*Alnus glutinosa*), where the galls are produced by gall-gnats (*Cecidomyia urticæ*, *alni*), and on the midrib of Elm leaves (*Ulmus campestris*; see fig. 361⁶), where the galls are produced by a leaf-louse (*Tetraneura alba*).

The so-called turpentine gall-apples (*Carobe di Giude*; see fig. 362⁴), which

are caused by leaf-lice on various species of *Pistacia*, also belong to the covering class. The rudiment of a foliage-leaf, which in the normal course of events would have developed into a pinnate leaf with dark-green elliptical leaflets, grows out into a pod-like structure not unlike a locust-bean (fruit of *Ceratonia Siliqua*). These galls are longitudinally grooved, and it can be seen more or less distinctly that the furrows correspond to the edges of the leaflets, only here the leaflets have become wrapped in, very much thickened and elongated, and fused with one another. In the cavity inclosed by the fused leaflets lives a colony of leaf-lice (*Pemphigus cornicularius*) which have developed under the protection of the gall. When it is time for them to leave the cavity the top of the pod opens by the separation and bending back of the tips of the fused leaflets which form the wall of the cavity (see fig. 362⁴). The Chinese galls of commerce, produced also by Aphides (on *Rhus semialata*), develop much in the same way. They are hollow, irregularly pear-shaped structures with thin walls covered externally with a gray down. Two other covering galls which deserve special mention on account of their form arise on the petioles of the Poplar, particularly on the species *Populus nigra*, *pyramidalis*, and *dilatata*. The one, caused by a leaf-louse, *Pemphigus bursarius* (see fig. 362²), consists of a smooth expansion, red in colour externally, on the upper side of the grooved petiole. If the local swelling be cut through it is seen to be hollow, the cavity in which the leaf-lice live being shut in by thick fleshy walls. The fleshy tissue of the walls is formed by a growth of the cells round the place where the gall-producing insect has settled. A hole is formed at a point remote from the petiole (where the growing tissue met and formed a dome) as soon as the time comes for the inhabitants to make their exit. This is bordered by thick lips as shown in fig. 362². The other gall which appears on Poplar petioles, produced by *Pemphigus spirotheca*, is formed by the thickening of the edges of the grooved petiole, which rise up as fleshy cushions and meet above the depression. At the same time the petiole undergoes a spiral twisting, and a gall is thus produced whose cavity is spirally twisted like the interior of a snail's shell. The thickened edges of the petiole do not fuse; at first they fit close to one another, but later on they separate, and a spiral hole out of which the white, downy leaf-louse can creep is the result (see fig. 360¹, p. 531).

We will now leave the mantle-galls and pass on to a consideration of the *solid* or *tubercular galls*. These are of the nature of swellings of limited size on single plant-organs, and are produced by insects which *pierce the plant-tissue and lay their eggs in the wound*. In this way either the epidermis of the chosen spot alone is injured, or the egg is inserted into the deeper-lying tissues. In both cases an active cell-division is incited in the neighbourhood of the injury. If, however, the egg has only been deposited in the epidermis, the larva which arises from it must penetrate into the interior of the now swollen tissue; when the egg is laid at once deep down this farther penetration on the part of the larva is of course unnecessary. The cavity in which the larvæ dwell may be called the larval chamber, and this sort of gall can be classified according to the number of chambers which it contains,

whether only one or several (*cf.* figs. 363² and 363⁷). A great variety is met with in the structure of the wall of the larval chamber. It always has a layer of juicy, thin-walled cells immediately surrounding the egg, known as the medulla or pith of the gall, and an outer layer which surrounds the inner like a skin or bark (see fig. 360¹⁰). In most instances a third layer is inserted between them which consists of very hard cells forming a protective layer. It should also be noted that the layers of the wall of the gall separate in many instances, so that it is possible to distinguish an "inner" and an "outer gall". The gall-pith furnishes the larva with food when it emerges from the egg, and for this purpose the cells are stored with nourishing substances. The development of the pith takes place with great rapidity, and begins as soon as the egg has been laid in the tissue. The larva when hatched finds the inner wall of the chamber which has been fitted for its temporary abode always provided with the necessary food, and it immediately attacks and devours the juicy tissue with great avidity. The cells which are demolished, wonderful to relate, are replaced almost at once. The cells of the gall-pith remain capable of division as long as the larva in the chamber requires food, and the surface cells which have been devoured in the gall-chamber are soon replaced by new cells from below, just as grass which has been mown down or cropped by cattle in a meadow sends up new stems and leaves. The spheroidal gall arising on the leaves of *Salix incana* (*cf.* fig. 360⁹) has only one chamber, and here the larva lives at the expense of the starch and other food-materials contained in the extremely thin-walled cells which constitute the gall-pith (fig. 360¹¹). The larva traverses the chamber in a circle, beginning the destruction of the cells at a certain place and eating on as it continues its peregrination (fig. 360¹⁰). New cells have already been formed for its nourishment by the time it again reaches the place from which it started.

The hard and cortical layers are modified in very many ways as protective measures against the drying up of the gall in summer on the one hand, and against the attacks of birds and larger animals on the other. For the latter purpose the cortical layer is often fashioned like the pericarps of fruits which have to protect the seeds (*cf.* p. 442). This also explains the bitter substances, hard skin, furry coat, bristling processes, and numerous other protective structures which are developed in and on galls just as on pericarps, and which contribute not a little to the remarkable similarity between galls and fruits. Many peculiar developments on the surface of these fruit-like galls cannot indeed be explained in this way, but, as in so many other cases, we conclude that they must afford some other advantage concerning which our understanding is still at fault.

The external similarity between fruits and solid galls affords us useful points for classifying the latter into groups, which we may name berry-like, plum-like, apple-like, nut-like, capsule-like, &c. The currant gall produced by *Spathogaster baccarum* on the male catkins of the Oak has not only the form and size of a Red Currant berry, but is also succulent and coloured red, and when several of these galls are formed on the same inflorescence it looks at first sight just as if racemes

of red currants had been borne by some chance or other on Oak twigs. The galls produced by the Beech-gall gnat (*Hormomyia fagi*) on the foliage of the Beech resemble small plums, being surrounded by a hard layer which consists of a stone kernel and a layer of cells which might be compared to the fleshy part of a plum. The galls caused by gall-wasps of the genus *Aulax* on the nutlets of many Labiatae, especially on *Nepeta Pannonica* and *Salvia officinalis* also assume the form of stone-fruits. The insect lays its eggs in one of the four nutlets developed at the base of each flower; and within a week this grows into a smooth greenish-yellow ball which has the external appearance of an unripe cherry. A section through it shows that it possesses also the same structure as a cherry, plum, or stone-fruit in general. The succulent outer layer surrounds a hard stony kernel, but in the cavity of the kernel there lies the white larva of the gall-producer instead of the seed. These galls fall off just like fruits in July, and lie on the ground during the winter; and the mature insect does not bite an opening in the wall of the gall through which it can emerge until the following year. It has been already remarked at the beginning of this section how strong is the resemblance between apple-fruits and the spherical oak-galls, known as oak-apples, which are produced by various Cynipedes (see fig. 364³), together with the small red-cheeked galls produced by *Rhodites Eglanteriae* and *Nematus gallarum* (see figs. 361² and 361⁷) on Rose and Willow leaves respectively. Pith-galls which resemble certain dry fruits are very common. Those produced on the green cortex of young Oak twigs by *Aphilothrix Sieboldi* (see fig. 364¹) remind one of the fruits of species of *Metrosideros*, those produced by *Neuroterus lanuginosus* and *Spathogaster tricolor* on the leaves of the Turkey Oak (*Quercus Cerris*; see figs. 364¹¹ and 364¹⁴) have a decided similarity to the indehiscent fruits of the Wood-ruff and of the Goose-grass (*Asperula odorata* and *Galium Aparine*). The "spangle" galls produced on Oak-leaves by the gall-wasps *Neuroterus fumipennis* and *numismatis* resemble the fruits of *Omphalodes* (see figs. 364¹² and 364¹³), and the galls on the leaves of *Duvaua longifolia* produced by an insect *Cecidoses Eremita* have the form of a capsule which opens by an operculum (see figs. 362⁵ and 362⁶). Like fruits these galls may appear in all imaginable conditions with smooth, warted, or rugged surfaces, or covered with woolly or velvety hairs, with bristles or spines, fringes or claws, or even with moss-like outgrowths. The galls with moss-like covering occurring on the Wild Rose have been known from remote times as Bedeguars. They are caused by the Rose-gall wasp (*Rhodites Rosæ*), which deposits its pointed, sometimes hooked eggs early in the spring in the substance of an undeveloped leaf while it is still folded up in the bud. The growth of the leaf becomes altered, the first sign being the development of numerous hairs. The larvæ, when they creep out of the eggs, penetrate deeper into the tissue of the leaf, and it swells out into a solid gall containing as many chambers as there are larvæ. Hairs and fringes continue to form on the exterior till those curious structures are formed which were said to have the power of inducing a peaceful sleep when laid under the pillow. Usually the stalks of the

young bud-leaves are pierced and then the upper portion of the leaf becomes atrophied. More rarely is the egg laid in the epidermis of one of the leaflets, in which case the leaves attain their normal size and only this particular leaflet is decorated with little bedeguars, as shown in fig. 361¹. When the petioles of three young leaf-rudiments are pierced simultaneously, as often happens, three single galls are produced close together on a shortened axis, and the whole structure may then attain the size of a pine-cone.

The portion of meristematic tissue which is pierced by the insect when it deposits its eggs sometimes remains an open passage; but more often a corky tissue is formed at the wounded spot which quite closes the chamber wherein the larva dwells. Under these circumstances the insect when it emerges must itself make an exit-passage from the gall, and this it does by biting a hole through it with its mandibles (see fig. 364³). The gall-wasps (*Cynipedes*) invariably leave the chamber which has hitherto served them both as a safe habitation and as an inexhaustible storehouse in this way. This does not occur, however, in some of those solid galls which owe their origin to gall-gnats of the genera *Hormomyia*, *Diplosis*, and *Cecidomyia*, for example, in those on the leaf-blade and petiole of the Aspen (*Populus tremula*) produced by *Diplosis tremulae* and on the leaves of Willows (*Salix Caprea*, *cinerea*, *grandifolia*) by *Hormomyia Capreae*. Here the exit-passage is formed during the development of the pith. The gall consists, as in most other solid galls, of a pith, a hard layer, and an epidermis, but the enormously developed pith and the hard layer do not quite entirely surround the small larval chamber, they leave a small aperture on the part of the gall which is most arched. As long as the epidermis stretches over this place the mouth of the passage is of course not evident, but when the time comes for the insect to quit the chamber a gaping slit is spontaneously formed in the tense epidermis. In many instances the insect or the pupa as it pushes forward may break through the thin skin. A peculiar closure which might be compared to a lid is formed in the common solid galls which are produced so abundantly on Beech leaves by *Hormomyia fagi* and which have been already alluded to. Just as the pupa of many *Lepidoptera* projects out of the hole in the cocoon which the caterpillar has spun for it far enough to allow the insect to fly away uninjured when it emerges, so that of *Hormomyia fagi* presses through the lid-like closure at the base of the gall, and the winged insect comes out leaving the chrysalis-case behind it.

The opening of some solid galls, which resemble operculate capsules, and which may be termed capsule-galls, is especially remarkable and requires a more detailed description. As long as the larva or grub can remain and obtain food in the larval chamber the gall is completely closed, but when the time approaches for it to move its quarters and to enter the pupal stage in the ground a circular line of separation is formed in the tissue, and the part of the wall within the circle comes away as a lid. The process is seen very prettily in the gall produced on the leaves of the Turkey Oak (*Quercus Cerris*) by the gall-gnat *Cecidomyia cerris* (see fig. 362⁷). In its closed condition the gall is a firm rounded chamber

so embedded in the leaf that it projects on the upper side as a small pointed cone, and on the lower side as a disc covered with a thick coating of hairs. In the autumn a circular piece like a lid becomes detached from the lower side of the chamber. It corresponds exactly with the extent of the hairy disc, and is so sharply defined that it looks as if it had been cut out with a knife (see figs. 362⁸ and 362⁹). The operculum falls off, and the larva which had emerged from the egg and which has lived all the summer in the gall-chamber tumbles out and makes its way into the ground, where it begins to spin. By the next spring it has entered the pupal stage, and the gall-gnat creeps out of the chrysalis about May.

Still more peculiar are the galls produced by *Cecidoses Eremita* on the green

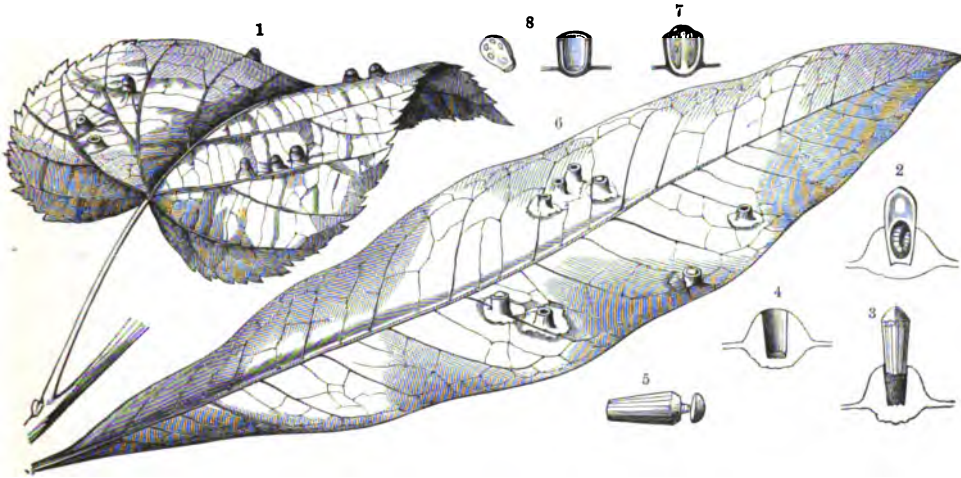


Fig. 363.—Solid Galls.

¹ Capsule-like galls on a leaf of the Broad-leaved Lime (*Tilia grandifolia*) produced by *Hormomyia Réaumuriana*. ² Longitudinal section through one of the galls, showing the maggot in the interior; $\times 2$. ³ Longitudinal section through a capsule gall from which the inner gall is just being extruded; $\times 2$. ⁴ Outer gall after the extrusion of the inner gall; $\times 2$. ⁵ Inner gall at the moment when the operculum is thrown off; $\times 2$. ⁶ Capsule-galls on the leaf of a Brazilian species of *Celastrus*. ⁷ Longitudinal section through one of these galls; $\times 2$. ⁸ The same after the inner gall has fallen out; $\times 2$. ⁹ and ¹⁰ natural size.

cortical tissue of young twigs of *Duvaua longifolia*, a South American representative of the Anacardiaceæ (see figs. 362⁵ and 362⁶). The gall is quite spherical and very hard, and its large cavity conceals the caterpillar which has been hatched from the egg. When the time draws near for the formation of the pupa, a plug with a projecting rim is developed on the side of the gall furthest from its point of attachment. When the plug is pushed out a circular hole is left which leads into the gall-chamber through which the caterpillar escapes from its dwelling. People who have not seen these galls with their own eyes might almost think this description was the work of imagination. And yet there are still more wonderful forms in this class of gall-structures. On the foliage of the Lime (*Tilia grandifolia*) a growth arises round the eggs of the gall-gnat *Hormomyia Réaumuriana* which at first has the form of a flat lens inserted in the green tissue of the blade, but which gradually enlarges until it projects from the upper side like a

blunt cone and from the lower as a hemispherical wart. The gall-chamber is inhabited by the maggot of the gall-gnat. The top of the conical part loses its colour in July and becomes yellow and brown, and a rim is formed around its summit. On cutting a vertical section through the gall at this stage it is seen that the tissue forming the wall of the chamber consists of two parts (see figs. 363²). The inner layer, which contains the maggot, is surrounded by an outer one which gradually passes into the green substance of the leaf and extends up to the rim just mentioned. The whole structure has separated into an "outer" and an "inner" gall, the inner gall resembling an egg lying in an egg-cup (cf. fig. 363³). During the summer the inner gall separates completely from the outer and is actually thrown off by it. For the accomplishment of this the tissue of the outer gall swells up very much, so that it exercises a pressure on the inner gall which is shaped not unlike a cone, somewhat narrower below than at the top (see fig. 363⁴). The extruded inner gall falls on the ground below the Lime-tree and assumes a dark-brown colour; the outer gall remains as a little crater embedded in the leaf-blade and ultimately shrivels up (cf. figs. 363¹ and 363⁴). The detached inner gall is smooth at the blunt and previously upper extremity, and striated at the other; it is not unlike a detached composite-fruit. The gall-gnat within feeds for a little time longer on the succulent lining, and then rests through the winter; in the spring it makes its escape. To do this it bites a ring-shaped groove below the conical top of the gall and presses against the roof, which, owing to the breaking of the tissues around the ring, comes away like a lid (see fig. 363⁵). A similar state of affairs prevails in a gall formed on the foliage of a Brazilian species of *Celastrus* (see figs. 363^{6, 7, 8}), but here the inner gall (which comes away) has several chambers, and the outer gall has the form of a cup set in the green blade.

The place of origin of all these solid galls depends of course upon the insects producing them. These are usually very fastidious about the place where they will lay their eggs, and it is truly astonishing with what care they search out spots difficult of access, and at once favourably situated as regards food supply and likely to afford a safe habitation for their offspring during the larval stages. The small gall-wasp *Blastophaga grossorum* lays its eggs in the ovaries of the "gall-flowers" in the interior of the figs of *Ficus Carica* (see p. 160 and figs. 240¹⁴ and 240¹⁵, p. 157). The gall-wasps *Andricus amenti* and *Neuroterus Schlechtendali* deposit them in the stamens of the Turkey Oak; the gall-wasp *Cynips caput-medusæ* lays hers in the side of the bract-scales which surround the pistillate flowers of the Oak (*Quercus sessiliflora* and *pubescens*), and so produces a gall with innumerable stiff-pointed fringes entangled with one another which ward off the attacks of other animals (see fig. 364¹⁰). Countless gall-producing insects deposit their eggs on the lower side of foliage leaves, some preferring the lamina, others the veins. *Andricus curvator* prefers the margin of Oak leaves, *Diplosis tremulæ* the petiole of the Aspen at its junction with the blade. Several gall-wasps, as, for example, *Andricus æstivalis* and *Andricus grossulariæ*, seek out the floral receptacle in the male catkins of the Turkey Oak for the deposition of their eggs, whilst

several Cynipides, e.g. *Aphilothrix Sieboldi* (see fig. 364¹) lay their eggs in the green cortex of the young twigs. Solid galls are very rare on roots, but they do occur

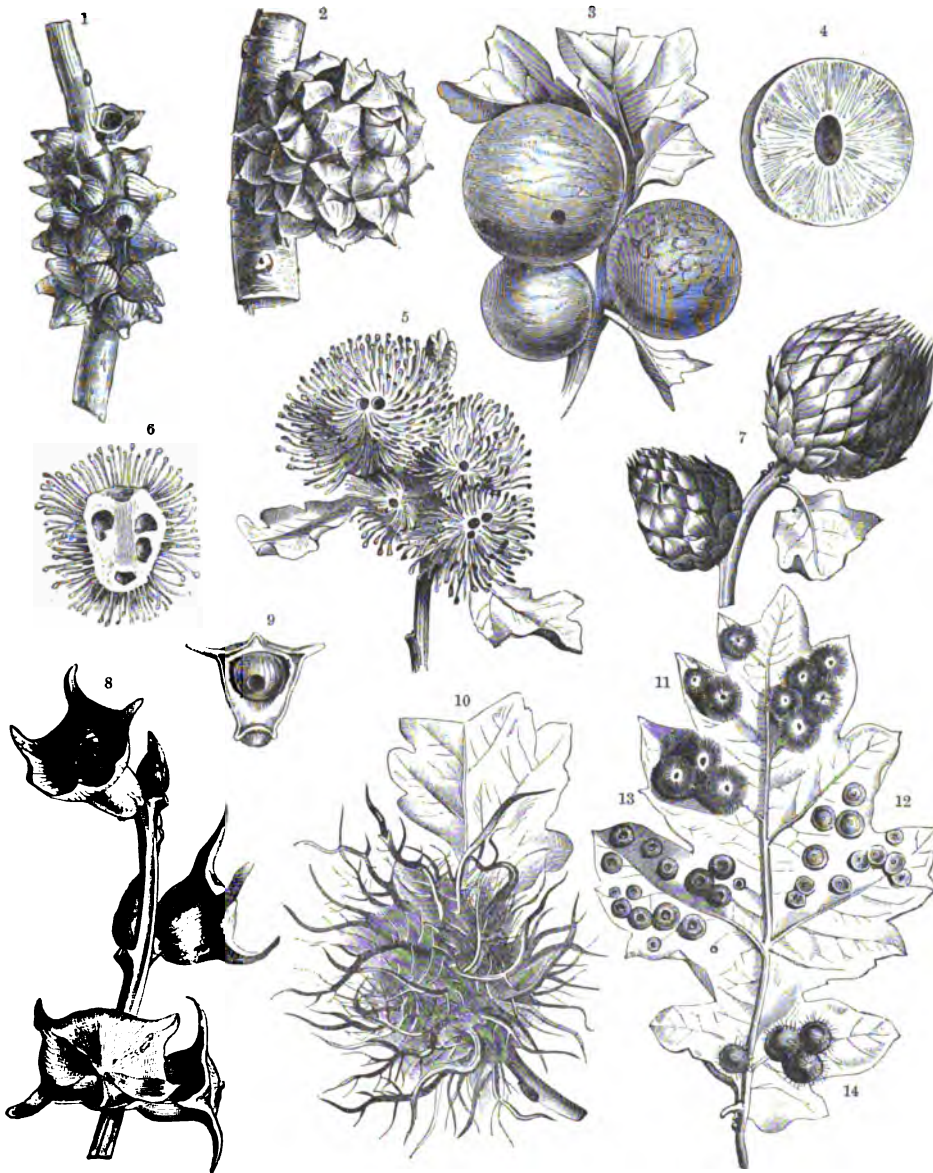


Fig. 364.—Various Oak-galls.

- ¹ Solid galls on the cortex produced by *Aphilothrix Sieboldi*. ² Bud-gall from a foliage-bud produced by *Cynips Hartigii*. ³ Solid galls on an Oak twig produced by *Cynips Kollar*. ⁴ One of these galls cut in half. ⁵ Bud-galls from foliage-buds produced by *Cynips lucida*. ⁶ One of these galls cut in half. ⁷ Leafy bud-galls produced by *Aphilothrix gemma*. ⁸ Bud-galls from foliage-buds produced by *Cynips polycera*. ⁹ Longitudinal section through one of these galls. ¹⁰ Gall on the pericarp of *Quercus pubescens* produced by *Cynips caput-medusae*. ¹¹⁻¹⁴ Spangle galls on a leaf of the Turkey Oak (*Quercus Cerris*); ¹¹ produced by *Neuroterus lanuginosus*; ¹² by *Neuroterus numismatis*; ¹³ by *Neuroterus fumipennis*; ¹⁴ by *Spathogaster tricolor*.

in this situation in the oak, being produced by the gall-wasps *Aphilothrix radialis* and *Biorhiza aptera*.

When several organs of a plant immediately adjacent to one another are concerned in the production of a gall it is said to be *compound*. Compound galls are for the most part produced from buds, and they are all comprehended under the general name of *Bud-galls*. They are extraordinarily varied in their characters, some being merely abbreviated axes clothed with scale-like leaves, in others only the base of the shoot is involved and above the gall it continues its growth quite normally, whilst in others again the axial portion of the structure is much swollen, and the leaves hardly represented at all. It is difficult to give any satisfactory classification of these bud-galls; still, for the sake of arranging our facts, we may distinguish these types, viz.:—the *ordinary bud-gall*, the *cuckoo-gall*, and *cluster-gall*. Ordinary bud-galls involve several, often all, the members of a shoot. The axis of the shoot is always deformed and abnormally thickened. The swollen portion contains in its interior one or several larval chambers surrounded by a pith-like layer. Two varieties of ordinary bud-gall may be distinguished. The first is leafless; no leaves are present, or, more correctly, they are transformed into tubercles, pegs, and knobs which merge insensibly into the swollen axis which contains the larval chamber. The second possesses leaves, the gall being covered with scale-like bracts or more or less fully developed green foliage-leaves. Amongst the leafless bud-galls the most interesting are those which are armed with special means of protection against the attacks of animals on the watch for the larvæ of the gall-wasps. The gall shown in figs. 364³ and 364⁹, produced by *Cynips polycera* on the leaf-buds of *Quercus pubescens* and *sessiliflora*, which to a certain extent affects a whole lateral shoot, has the form of a young Medlar fruit, and on it may be seen 3–5 metamorphosed leaf-structures projecting as stiff-pointed pegs which gradually pass into the tissue of the shoot axis. This gall is one-chambered, and the tissue of the wall has separated into an outer layer and an inner spherical pithy gall. The gall shown in fig. 364² is produced by the gall-wasp *Cynips Hartigii* which lays an egg in the middle of the leaf-bud of the Oak (*Quercus sessiliflora*). The bud does not develop into a leafy shoot, but into a small one-chambered gall with large tooth-like or club-like processes which represent metamorphosed leaves. The thickened angular ends of these projections fit closely to one another so as to form a sort of second outer coat to the gall-chamber through which hostile ichneumon-flies cannot penetrate. The gall much resembles the cone-fruit of a Cypress in the arrangement and form of its superficial processes. The galls produced from the buds of various Oaks (*Quercus pendulina*, *sessiliflora*, *pubescens*) by the gall-wasp *Cynips lucida* are still more peculiar (see figs. 364⁵ and 364⁶). They contain several larval chambers with abundant pithy tissue, whilst innumerable slender processes resembling limed twigs in being very sticky on the capitate thickened end project from their exterior. Ichneumon-flies and other animals hostile to the gall-producers take good care not to come into contact with these spikes which are to be regarded probably as transformed leaves springing from the swollen axis. Among the galls produced from leaf-buds belonging to this group there are some in which the leaves are merely indicated as tubercles. This is the case, for example, in the many-chambered,

spongy gall, red-cheeked on the sunny side but pale elsewhere, which is produced on the tips of the branches of the Oak by the gall-wasp *Dryoterus terminalis*, and looks very like a potato in shape. The leaves are only represented by small ill-defined knobs and ridges, just as in the potato. To this class of galls belongs also that to which the term "nut" is popularly applied, and even in commerce, the name has been transferred from this to the whole of the first group of compound galls (bud-galls). The "nut" is produced on the Oak by *Cynips calicis* as an angular and irregularly-grooved gall which originates at the end of a flower axis, and the cupule formed of several bract-scales as well as the ovaries are concerned in the growth. This class of galls also includes the irregular blunt swellings on Aspen twigs (*Populus tremula*), which are caused by the larva of a beetle (*Saperda populnea*), and in addition the many-chambered woody "canker cushions" as large as a nut which are produced on the branches of Willows by *Nematus medullaris*.

The gall shown in fig. 364⁷, which arises on various Oaks (*Quercus pedunculata*, *sessiliflora*, *pubescens*) by the action of the gall-wasp, *Aphilothrix gemmæ*, may be selected as a type of leafy bud-galls. It resembles the cone of a Hop or Larch, and is developed from a foliage-bud. It has a much-abbreviated swollen axis, whose tissue separates into an inner and outer gall, beset with numerous dry, brown lanceolate hairy scales having the form of bract-scales. Bud-galls which are covered with green foliage-leaves are produced by the gall-wasp *Andricus inflator* on the Oak, but they are more commonly met with on herbaceous plants, e.g. by *Urophora cardui* on *Cirsium arvense*, by *Diastrophus Scabiosæ* on several Knapweeds (*Centaurea alpestris*, *C. Badensis*, *C. Scabiosa*), by *Aulax Hieracii* on various Hawkweeds (*Hieracium murorum*, *sylvaticum*, *tridentatum*, &c.). Usually the foliage-leaves are stunted, and not infrequently the blades of some of them are quite obliterated, so that the gall in that region is only furnished with scaly leaf-sheaths. A Sage growing in the Isle of Crete so often bears leafy bud-galls resembling a small Quince-apple, produced by a species of *Aulax*, that Linnæus called it *Salvia pomifera*. The stem of this Sage is swollen out like a ball, and the spherical mass, covered with a gray felt of hairs on the exterior, is surmounted at the top with a group of small wrinkled leaves, which look like the persistent calyx of a Quince-apple. The best known and most widely distributed of these forms, found on the Hawkweeds named above, consist of knob-like swellings of the stem. The larval chamber is situated inside the enlarged pith, the ring of vascular bundles, which has undergone much shifting, forms the protective layer, and the cortex of the affected region of the stem forms the cortical layer of the gall. The epidermis is densely covered with hairs.

Leaving the galls which consist of modified foliage-buds, we pass on to such as consist of metamorphosed *flower-buds*. They arise from flower-buds in which small gall-gnats have laid their eggs. The larva hatched from the egg lives in the cavity of the ovary, or in one of its loculi when there are several, and this space, therefore, becomes the larval chamber. The corolla, which envelops the ovary in the flower-bud, remains closed, like a cap on the top of the larval chamber. The calyx becomes

inflated, enlarged, and sometimes fleshy. The whole gall resembles a bud or small bulb; it is not unlike one of those bulbils which so often arise instead of flowers on the flowering axis of certain species of *Allium*. They occur especially on the Bird's-foot Trefoil (*Lotus corniculatus*), where they are produced by the gall-gnat *Cecidomyia Loti*, on the various species of Mullein (*Verbascum Austriacum*, *nigrum*, *Lychnitis*, &c.) by *Cecidomyia Verbasci*, on several species of Germander (*Teucrium montanum*, *Scordium*, &c.), caused by *Lactomelopus Teucrii*, and on the Rampion (*Phyteuma orbiculare*), where they are produced by *Cecidomyia phyteumatis*.

Closely allied to these bud-galls are those remarkable gall-structures which are commonly known in Austria as "cuckoo-buds". The cuckoo is supposed to be concerned in their formation, just as it is in that of the frothy saliva-like masses deposited by the *Cicada* on the Cuckoo-flower (*Cardamine pratensis*). The name "cuckoo-galls" may be employed for the whole of this sub-group. They are characterized by their pale whitish colour, soft spongy tissue, and especially by the fact that they only involve the *base* of the shoot, while the upper end can continue its growth unaltered. In this respect they may be compared to a Pine-apple fruit, where the axis rises above the fleshy collective fruit (*cf.* p. 436) as a green leafy tuft, which does not lose its growing power even with the ripening of the fruit. The history of the development of cuckoo-galls is probably like that of covering galls; and the main distinction lies in the fact that in the former the gall is produced not merely from a *single* organ or some part of it, but from a *whole group* of adjoining plant-members. The best known and most widely distributed gall of this group is produced by the pine-apple aphid *Chermes abietis* on the twigs of the Spruce Fir (*Abies excelsa*, see fig. 362¹, p. 534). Early in the spring, before the foliage-leaves have begun to unfold, the parthenogenetic females, the foundresses of the colony, attach themselves each to the base of a young leaf and lay a mass of eggs at the spot to which they have adhered. The larvæ, hatching, penetrate the surrounding parts of the shoot with their beaks; the shoot swells, as do the bases of the needles, and a growth, the Spruce gall or Pine-apple gall results. The gall somewhat resembles a small Fir-cone about an inch long, with the surface divided into small convex areas, each bearing a short needle-like projection in the middle; these are the deformed needles, which, becoming swollen, touch each other on the outside of the gall. They are separate inside, so that the gall contains a series of cavities or chambers. In these chambers the larvæ live in numbers, either entering the chambers during the growth of the gall or being inclosed by the swelling of the surrounding needles—this point is not certainly determined. They remain in the small cavities so formed and feed, cast their skins, and multiply there. In August the gall begins to dry up, each of the small cavities opens by a slit in front of the green needle-point surmounting the cushion (see fig. 362¹, p. 534), and the winged insects now leave the place in which they have passed the spring and summer.

Cuckoo-galls are met with almost as frequently on *Stellatæ*, viz. on various species of Bedstraw (*Galium Austriacum*, *boreale*, *uliginosum*, &c.) and Woodruff

(*Asperula galioides*, *tinctoria*, &c.) as on Fir-trees. The infected parts of the shoot remain stunted, and white spongy cushion-shaped growths, which are somewhat grooved, arise at the bases of the leaves. Since the growing tissues of neighbouring leaves touch one another the grooves or channels form small cavities in which live the larvæ of the gall-producing gnats (*Cecidomyia Galii* and *Asperulæ*). In the common Bedstraw (*Galium Mollugo*) these spongy growths arise, not from the bases of the leaves, but from the green cortex of the stem round the insertion of the leaves and lateral branches. They rise up as cushions and lobes, and several join together to form a sort of dome, under which the larvæ of the gall-gnat dwell. The foliage-leaves are scarcely altered in form, and when lateral twigs arise from the place they also are unchanged. It not infrequently happens that short lateral axes terminated by flowers spring up quite unmodified above the spongy white cuckoo-gall. Cuckoo-galls also occur on Cruciferæ, viz. on *Barbaræa vulgaris*, *Nasturtium palustre*, *sylvestre*, and *Sisymbrium Sophia*. They are produced by *Cecidomyia Sisymbrii*, and originate principally at the bases of the flower-stalks half-way up the inflorescences. They look like spongy white bodies which surround the pedicels like the brim of a hat. As the growths from neighbouring pedicels meet together they roof over chambers which serve as habitations for the larvæ of the gall-gnats. Viewed from outside the galls appear like irregular white bodies inserted in the inflorescence, which remind one of the fruit of the white Mulberry-tree.

The term *cluster-gall* is reserved for that type of bud-gall in which the axis is much restricted or stunted and covered with densely crowded leaf-structures; it is in the chinks and recesses between the crowded leaves of these galls that the insects concerned pass the whole or a portion of their lives. The animals which cause the galls belong to very different classes. Gnats, leaf-fleas, leaf-lice, and mites are the commonest varieties. The gnats only live in the galls during the egg and larval stages, but the others pass their whole life there. They invariably settle on the end of a shoot while it is still undeveloped in the bud. The axis of the shoot remains more or less stunted in consequence of the influence the animals exercise on it and its leaves undergo fundamental alterations. The blade or sheath of the leaf is deepened and hollowed to afford sufficient space to the animals which have established themselves between them, and as these parts of the leaves touch one another recesses are formed not unlike those which are developed in fir-cones for the growing seeds. The sheathing part of the leaf is often rather thickened, and its succulent cells serve as food for the animals living in the gall; in other instances the hollowed leaf-blades are thickly covered with hairs, and this coat then has the same significance with regard to the insects as the felt of hairs on isolated leaves already described. Very different forms of galls are produced according as to whether the free ends of the leaves turn back or remain in contact, and whether the axis from which the leaves spring is more or less contracted. Sometimes they remind one of open rosettes, sometimes of closed balls, bunches and tufts, sometimes of pig-tails and witches' brooms.

Clustered galls may be divided into two classes, those which develop in the region of the *flowers* and those in the *foliage* region respectively. The most noticeable and best known forms of the galls occurring in the foliage region on rudimentary leafy shoots are the following:—First, those peculiar structures on the tops of Willow twigs (*Salix aurita*, *Caprea*, *grandifolia*, &c.) which are popularly termed “Rose Willows”. They are caused by the gall-gnat *Cecidomyia rosaria*. The leaf-bud from which they arise keeps its axis quite short and develops on it numerous green leaves arranged like the petals of a double rose. The lowest leaves of the “rose” differ but slightly from the normal foliage of the particular species of Willow. Usually there seems to be only a shortening and broadening of the petiole and leaf-sheath, the green blade being almost unaltered. In the upper inner leaves, however, the sheath-like part of the leaf is much increased in size, and nearer the centre of the “rose” the leaves become scale-like. The leaf-blade has entirely disappeared, and the end of the contracted axis possesses only the remains of leaf-sheaths. It is worth noting that the number of leaves in a Rose Willow is always greater than would be found on an unaltered shoot of the same species. For example, if the number of leaves on the one-year-old shoot of the Sallow (*Salix Caprea*) is 25, the number in a “rose” on the same species would be at least twice as large. This can only be explained by supposing that a “prolepsis” has occurred, *i.e.* that not only the shoot laid down for the current year has developed, but also one originating from a bud of this shoot, which, under normal conditions, would not have developed until the following year. When autumn comes the rosette-shaped galls on the Willow bushes show up conspicuously at a distance because the leaves forming them do not fall off like the rest, but remain behind as brown dried structures at the ends of the branches. They are also found associated with the catkins. The rosette-shaped galls produced by the gall-gnat *Cecidomyia crataegi* at the tips of Hawthorn twigs (*Crataegus Oxyacantha* and *monogyna*) also claim attention. They are full of bristles and resemble tiny birds’ nests. The stimulus of the gnat larvæ excites a deeper and more frequent segmentation in the leaves and stipules. Narrower points and fringes which are much bent and which resemble the antlers of reindeers replace the broad lobes. Also soft spines with capitate ends rise up from the green cortex of the twigs and from the tissue of the leaf-blade, especially above the vascular bundles, and 3–5 of them often fuse together into cock’s-comb-like structures. These bristling rosettes on Hawthorn branches also remain long after the time the ordinary foliage falls off.

In marked contrast to the rosette-like cluster-galls are others whose leaves all fold together in a ball something like the leaves of a cabbage, the whole gall having a button-like appearance. The outer leaves are round and hollowed on their upper side, and they usually fold together like mussel-shells. The inner leaves have a similar form, but they are much smaller and more concave, and they have become succulent and paler in colour. The galls produced by *Cecidomyia genisticola* on *Genista tinctoria* and those which *Cecidomyia Veronicae*

gives rise to on *Veronica chamædrys*, and which gall-mites produce on the Wild Thyme (*Thymus Serpyllum*; see figs. 360⁴ and 360⁵, p. 531), form white buttons on the ends of the shoots which show up conspicuously from the dark green of the surrounding foliage. The white colour is due to the fact that the outer leaves, which fold together like mussel-shells, are thickly covered on the outside with white hairs. *Cecidomyia Artemisiæ* produces on the branches of *Artemisia campestris* a closed cluster-gall which is cased in white wool like a shroud. On the other hand, the large, button-shaped, closed cluster-galls which are produced by *Cecidomyia rosaria* on Willows (*Salix purpurea*, &c.) and by a gall-mite on the spikes of the Brome-grass (*Bromus*) are green and smooth, or at least they have not more than the usual number of hairs.

On the shoots of the Yew (*Taxus baccata*), the Flax (*Linum usitatissimum*), *Euphorbia Cyparissias*, the Moss Campion (*Silene acaulis*), and several *Ericas* (*Erica arborea*, *carnea*, &c.) the influence of various gnats (*Cecidomyia Taxi*, *Euphorbiæ*, *Ericæ*, *scopariæ*, &c.) produces galls with linear erect leaves crowded together into tufts. The base of the crowded leaves and the axis of the gall are usually rather thickened, so that it looks as if the linear leaves were set on a rounded button, and this is particularly marked in *Euphorbia Cyparissias*. This division includes the gall formations occurring on Juniper twigs (*Juniperus communis*), which are caused by the gall-gnat *Lasioptera juniperina*. The acicular leaves of the Juniper are arranged in whorls of three on normal shoots. By reason of the influence of the gall-gnat *Hormomyia juniperina* the whorls at the top of the twig become so changed that the last but one represents a cup bordered with three teeth in consequence of the broadening of the needles, while the terminal whorl is metamorphosed into a dwelling surrounded by three short leaflets. This gall closely resembles the cone of the Arbor Vitæ (*Thuja occidentalis*, *orientalis*, and *plicata*) in form.

An insect, *Livia Juncorum*, produces galls on various Rushes (*Juncus*), especially *Juncus alpinus* and *lamprocarpus*, which look like knots or tassels. The axis of the shoot is contracted, the sheathing portions of the leaves which cover one another are much widened, and the colour is pale except where it is reddened by exposure to the sun; their appearance is like the outer covering or top of a tassel. The stunted green blades which spring from the sheathing portions are thread-like and arranged as the loose strands of the tassel. Not infrequently short lateral shoots arise in the axils of some of the leaves, and then the whole structure looks like a bunch of tassels.

Closely allied to these cluster-galls on the stems of Rushes are such as resemble tufts and witches' brooms, produced by mites on the branches of hairy Willows, especially on the white Willow (*Salix alba*). Instead of the long leafy Willow rod which would have emerged under ordinary circumstances from a foliage-bud, a confused mass of twigs with short leaf-scales is developed which at first seems a perfect mystery. By careful examination it is seen that the axis of the shoot laid down in the bud has remained stunted, and that lateral

shoots have developed from the axils of its leaves. These lateral shoots again develop lateral axes in the axils of their leaves, and so on to the third, fourth, and fifth degree. Thus, in the course of a month, shoots have unfolded, which, except for the influence of the gall-mites, would not have followed one another for three, four, five, or even six years, and therefore these galls afford us another instance of what has been termed "prolepsis" or precocious development of structures which would not yet arise. Of course all the axes of these shoots are dwarfed and the leaves which clothe them are diminished in size. The shortening and diminishing increase gradually, so that the axes and leaves of the fourth and fifth degree are much smaller than those of the second and third. The last lateral shoots remain bud-like, and their small scaly leaves fold over one another like the bracts in the involucre of a Composite. The "witches' brooms" which are caused by gall-mites on Lilac (*Syringa vulgaris*) and Privet (*Ligustrum vulgare*) bushes are similar in nature to these closed galls on the Willows. Frequently the metamorphosis of the leaves on the axes of the third, fourth, and fifth degree includes those of the floral region, and such cases form to some extent a bond of union between cluster-galls on foliage and on floral regions, respectively.

One of the most remarkable changes exhibited by the gall-structures just mentioned, viz. the abbreviation of the axis, is of course not to be noted in cluster-galls in the floral region. The part of the axis which forms the floral receptacle does not grow into an elongated shoot, but always remains short, and the floral-leaves it bears stand close to one another, forming whorls in whose niches and recesses numerous small animals can hide. But these animals effect other very marked alterations by their stimulus. In some flowers, instead of the normal red, blue, white, or yellow petals, green leaflets appear which resemble foliage-leaves in character, and then we say that the flowers have become "green" or "leafy". In other plants the stamens are transformed into petals, and the flowers are said to be "double". Finally, it may happen that the carpels which are usually united together to form a syncarpous ovary stand on the receptacle as distinct structures, and that to a certain extent their union has been dissolved. In these cases we speak of "antholysis" (cf. p. 80). The influence of gall-mites also produces metamorphosed flowers which may be both green and double, and in which the pistil may have separated into its individual carpels.

The best flowers for observing these metamorphoses in all imaginable degrees are the small-flowered species of the Chickweed genus (*Cerastium macrocarpum*, *triviale*, &c.), several Caryophyllaceæ (*Lychnis Viscaria*, *Saponaria officinalis*, &c.), Cruciferæ (*Cardamine uliginosa*, *Camelina sativa*, *Lepidium Draba*), Gentians (*Gentiana acaulis*, *rhætica*), Speedwells (*Veronica officinalis*, *saxatilis*) and Milfoils (*Achillea Millefolium*, *nana*). In Speedwells the petals come to resemble leaves. The bunches, rosettes, and balls of small green leaves replacing the flowers are set close together on the rachis of the inflorescence and form green racemes and tufts, sometimes even small witches' brooms. In *Veronica saxatilis* the rachis of the raceme, the pedicels, and the bracts are covered with hairs, which

is not the case when the plants are free from the mites; the foliage-leaves in the neighbourhood of the raceme are also lobed and deeply indented, which again is not the case in uninfected plants of this species. In the capitula of the above-named Milfoils the peripheral ray-florets as well as the central tubular ones become leaf-like, and this gives rise to the most peculiar forms. A capitulum is often separated into several stalked sub-capitula, the flowers being metamorphosed into green funnels with jagged mouths, and into small flat-lobed and toothed foliage-leaves, whilst short, green, scale-like leaflets rise from the midribs of these leaves representing the metamorphosed stamens. A very remarkable "doubling" produced by gall-gnats is to be observed in flowers of the Alpine Rose (*Rhododendron ferrugineum*). The stamens and carpels are changed into red petals by their influence. Since *Rhododendron* flowers have ten stamens and five carpels, there should be only fifteen red leaflets in the centre of each, but as a matter of fact there are double and treble as many, and there has been not merely a metamorphosis but also a multiplication of the leaves. The flowers of some plants which belong to the Valerians, especially of the Corn-salad (*Valerianella carinata*), of which a small umbellate cyme is shown in fig. 358², p. 523, are doubled by the influence of a gall-mite, but without any multiplication of the petals. The doubling is restricted to the transformation of the stamens into a whorl of petals. But we also have another peculiar alteration. The petals become enlarged to more than fifty times their normal size, and change into fleshy lobes which are fused with one another into a disc. As all these lobes bend back, and become concave below, cavities are formed under the flowers in which the gall-mites can dwell (see fig. 358³, p. 523).

The axis of the inflorescence and the stalks of single flowers are often thickened and fleshy in these cluster-galls, and they are also stunted and bent in the most varied manner. If several neighbouring pedicels fuse together, structures like cocks'-combs, or like a compressed and flattened branch, arise; to these the term *fasciation* is applied. Sometimes when numerous pedicels arranged in the form of umbels fuse together we have structures like coral-colonies, or irregular clumps which are beset with green flowers usually much reduced in size. This is the case in the fasciations of the Ash (*Fraxinus excelsior* and *Ornus*), which are caused by a gall-mite (*Phytoptus*), and which occur so abundantly that it looks as if the tops of the trees had been sown with them.

The enumeration, here, of various forms of galls commenced with the inconspicuous felt-galls on the under side of isolated foliage-leaves, and it ends with the complex cluster-gall, in which hundreds of flower-stalks and leaves are frequently concerned. Of course, only types of the individual groups which have been mentioned in this long series could be instanced, and we cannot make any attempt to describe all the gall-structures at present known, about 1600 in number. Whether the extension of gall-researches in tropical regions will yield new forms which stand outside the pale of the classification given it is difficult to say. Apparently this will not be the case. Perhaps thousands of hitherto unknown galls might be added

to the list, but we should expect that they would fall under one or other of the above-mentioned groups.

Gall-structures have a peculiar significance for the section of the *Natural History of Plants* which deals with the question of the origin of species, since they show most distinctly how fundamental deviations from the original plan of construction may occur in the adult condition of a portion of a plant.

We must be careful to remember always that the immense variety of structures which we call galls would not have existed except for the effect produced on the plants by mites, leaf-lice, gnats, wasps, &c. The foliage of *Rhododendron* would not have been rolled up, but quite flat, if gall-mites had not been present; the branches of *Pistacia Lentiscus* would have borne pinnate foliage with shining dark-green leaflets and not fleshy-red pods if they had not been attacked by leaf-lice; the leaf-bud of *Quercus pubescens* would have developed into a long leafy shoot instead of a body like a medlar if the gall-wasp *Cynips polycera* had not provoked the change; the foliage of *Veronica saxatilis* would not have been lobed like a hand, but would have had a slightly sinuous margin; and the upper leaves of *Thymus* would have been green, spoon-shaped, and smooth on the surface instead of circular and covered with white hairs, had no gall-mites settled on them. The flowers of *Rhododendron ferrugineum*, *Lychnis Viscaria*, *Veronica*, *Cardamine*, &c., would not have "doubled", and the stamens would not have changed into petals, if they had not been under the influence of gall-mites.

Of course, the influence of the animals can only produce these effects on parts of plants which are in an embryonic condition. Mature stems and leaves may be eaten and destroyed by insects, but they can no longer be metamorphosed. But the undifferentiated rudiments upon which the influence is effective are, so to speak, formless. Leaves, stems, and fruits arise from tissue-masses having the form of tubercles and cushions, and each tubercle or cushion originates from a few cells which give no indication of what is to develop from them. Nevertheless, experience teaches us that the plan of construction for the plant-member proceeding from these primitive forms is definitely laid down from the beginning for each species, and the idea that the plan of construction is rooted in the specific constitution of the protoplasm of the plant—i.e. in the cell or cells which form the primitive stage or rudiment of the developing leaf, stem, &c., is confirmed. If an alteration in this plan of construction is produced by these animals, it can only be by some alteration of the specific constitution of the protoplasm.

How the alteration is effected is just the puzzle which is at present occupying the attention of naturalists. Once it was thought that the formation of galls was the result of injuries caused in the growing tissue by the ovipositor or sucking organ of insects, but recent investigations have not confirmed this view. The cells actually injured by the insect in laying its eggs perish, and consequently lose the power of metamorphosis or of producing modified daughter-cells. Cork, closing over the wound, is always formed from the adjoining living tissue, but for a long

time no gall is produced. The eggs deposited in the tissue, or attached to it, are also incapable of directly inciting gall-formation. There is no marked alteration in the neighbourhood until the grub or larva leaves the egg and excretes a fluid substance. Then growing cells of the most varied description are formed adjacent to the larva, and these rapidly assume the peculiar forms which have just been described. This, of course, applies also to cases where the larva has been hatched from the egg at some distance from the spot and has had to seek out a tissue suitable for its dwelling, as also to instances where adult gall-mites and leaf-lice choose out a suitable place for the deposition of their eggs and then secrete a fluid round them when they lay them. If the animal dies, the growth and renewal of the tissue immediately ceases. The cells round the dead body turn brown and die, so that we may conclude the formation of the gall to be due solely to the substance excreted by living animals.

Those who investigate galls consider that it is chiefly the acrid "saliva" excreted by the larvæ to liquefy their food which acts on the cell-tissue of the dwelling they have selected, but there is no doubt that other excretions may also take part. The chemical composition of this substance is unknown, but we shall hardly be wrong if we include it in the group of nitrogenous compounds called enzymes which were discussed at vol. i. p. 464. Enzymes have the power of altering and decomposing substances, even through the cell-wall, and in this way we can account very simply for a whole series of otherwise inexplicable phenomena in the formation of galls. Moreover, urea or closely-allied nitrogenous compounds may be excreted, so that there is nothing to be said against the view that some of the substances diffuse into the interior of the plant-cells. It is at least certain that the fluid substances excreted by the gall-producing animals, in whatever way they influence the protoplasm in the plant-cells, do not kill it, but actually stimulate it to an extraordinary new activity directly demonstrated by the production of tissues with a definite external form.

Observation shows that these tissues are formed and fashioned differently from what they would have been without the influence of this substance. It follows, therefore, that the substances excreted by the animals have the capacity of affecting in some way the specific constitution of the protoplasm which determines the species in the plant-cells influenced by them. It is specially interesting to note in this connection that it not only is the protoplasm of the cells directly acted on by the excretion which is stimulated to an altered form of constructive activity, but that this stimulus is transmitted from cell to cell in ever-widening circles. The spruce-fir aphid *Chermes abietis* attaches itself firmly by its beak to the scale of a Fir bud, and can directly influence only a few cells of the young shoot hidden in the bud. Nevertheless thousands of cells on this shoot soon begin to assume an altered form, a proceeding which reminds us strongly of the action of a ferment (*cf.* vol. i. p. 505), and also brings to our mind the influence exerted by the spermatoplasm on the ovary. The spermatoplasm is only directly concerned with a few cells in the ovule, but these propagate the influence on all sides to

the carpels and to the receptacle, and sometimes even to the flower-stalk. All these parts would not have developed as they have done had it not been that the minute quantity of spermatoplasm of a pollen-grain had united with a minute cell in the ovule.

It will be convenient to consider here the already mentioned similarity between galls and fruits. If the leaf-rudiments in the bud of a *Pistacia* shrub are not affected by leaf-lice they develop into shining green pinnate foliage-leaves; but if the protoplasm in some of the cells has been altered by the excretions of *Pemphigus cornicularius* this same rudiment will assume the form of a carpel, and become fashioned into a hollow body deceptively like a pod. The fact that the *Pistacia* shrub bears plum-fruits and not pods makes it still more remarkable, for the structure arising from the effect of the animal's excretion, when mature, is not like the fruit of the *Pistacia*, as we should naturally have expected, but like that of a completely different plant species, viz. the Carob (*Ceratonia Siliqua*). The same is true of the metamorphosis caused by the excretion of a gall-gnat (*Lasioptera juniperina*) on the uppermost leaves of the Juniper (*Juniperus communis*) which assume a form very like the fruit of the Arbor Vitæ (*Thuja*), and many other instances might be mentioned in which galls are produced in certain species of plants by animal excretions, looking outwardly very like the pods, capsules, nuts, drupes, and berries of other species. This resemblance to certain fruits is rendered the more pronounced by the development upon the galls of pigments, wax-like excretions, and hairy coverings, but of course they contain no seeds in their interior—only the larvæ of the animals whose excretions produce the changes of form. The wonderful thing is that the metamorphosis of the growing tissue into a fruit-like body is always of the greatest advantage to the animal which has settled in it, since the tissue serves not only for dwelling and food but also for protection against unfavourable weather and against the attack of foes.

It is also a fact of great importance that different animals produce differently shaped galls on the same plant. The Bedeguars produced by *Rhodites Rosæ*, the pea-like galls produced by *Rhodites eglanteriæ*, and the clustered protuberances produced by *Rhodites spinosissimæ* may all occur side by side on the same rose-leaf (see figs. 361^{1, 2, 3}, p. 533). On the same elm-leaf *Schizoneura Ulmi* produces a wrinkled gall, *Tetraneura Ulmi* a pocket-gall, and *Tetraneura alba* a covering gall (see figs. 361^{4, 5, 6}, p. 533). The spherical gall of *Nematus gallarum* and the bladder-like gall of *Nematus vesicator* occur close together on the foliage of the Purple Willow (see figs. 361⁷ and 361⁸), and one sees Oak-leaves on which the small spangle-galls of four different gall-wasps, viz. *Neuroterus lanuginosus*, *numismatis*, *fumipennis*, and *Spathegaster tricolor* are all present together (see figs. 364^{11, 12, 13, 14}, p. 541). It has been shown that some Oaks, for example, *Quercus pedunculata*, may bear as many as 20–30 different forms of gall produced by as many kinds of gall-wasps. The characteristic shape, colour, and hair-covering of these forms of gall is so constant that we can state with certainty what gall-wasps have given rise to them. These facts force us to the conclusion that the fluids

excreted by different gall-producing insects are specifically distinct. It is only in this way that we can account for the fact that the same vegetable protoplasm is incited in one case to produce a fleshy covering gall, in another a hollow pocket, and in a third a closed gall-apple as dwellings for the particular insects concerned.

It should also be mentioned that the same species of insect produces very similar but slightly different galls on different plants. For example, the gall produced by *Nematus pedunculi* on the lower side of the white-haired leaves of *Salix incana* is covered with a white felt of hairs, that which the same gall-gnat produces on the smooth leaves of *Salix purpurea* is smooth; the gall produced by *Rhodites Rosæ* on the light green leaves of *Rosa canina* is pale yellow and somewhat reddened on that side turned towards the sun; that on the violet leaves of *Rosa rubrifolia* produced by the same insect-species is dark violet, &c. These distinctions, though only insignificant, show how certain external characteristics founded in the specific constitution of the protoplasm of different plant-species find expression even in the gall-structures.

These facts confirm the view that the fluids excreted by different species of insects, as well as the protoplasm of each plant species, have a peculiar composition. It is then quite obvious that the alteration which the protoplasm of a species of plant undergoes under the influence of a specific fluid will be subject to definite laws. The protoplasm of the particular plant-cell receives by reason of the alteration, as it were, a new definite constitution with tendencies not the same as before; but since this constitution determines the outer form of the tissue derived from these cells, the tissue itself will become shaped into a particular specific form. These conclusions are of importance with respect to the question of the origin of new species, inasmuch as they throw some light on the processes which lead to the origin of new forms. We can now say that the alteration in the form of a plant only occurs if the constitution of the protoplasm which forms the starting-point of the plant is itself first altered.

The structures known as galls have not the power of maintaining and multiplying themselves, but when their task is ended they perish. In other words, the progeny arising from the seeds of a plant beset with galls exhibits none of the alterations shown by the members or shoots of the parent plant. If, for example, an Oak which is covered with galls is propagated by seeds, the offspring show no trace of the structural alterations exhibited by the branches, foliage, or flowers of the mother-plant. The only change which is perhaps sometimes retained in the offspring is the metamorphosis of the stamens into petals, which has long been known as doubling, and perhaps also the formation of fasciations, &c. in the floral region, as in Cabbages (where it is known as a Cauliflower). Few attempts have yet been made to investigate this matter. My own knowledge of the subject is restricted to some observations made on the Speedwell *Veronica officinalis*. Plants of *Veronica officinalis* which in consequence of the settlement of gall-mites on them produced double flowers in 1877 in the garden of my country house were planted close beside others free from gall-mites and with normal flowers. In the

following year the gall-mites settled on the latter also, and the greater part of their flowers then became double. The same result was obtained after living gall-mites were transferred by me to isolated plants of *Veronica officinalis* with single flowers. These in the following year also bore some double flowers. Fruits with ripe seeds were only produced from the flowers which had remained single amongst the double ones; and the plants which grew up from these seeds always bore single flowers only. The gall-mites disappeared for some unascertained reason—probably they died in the winter. *Veronica officinalis* has only two stamens in each flower, and in the double flowers both these and the two carpels are changed into petals so that of course we could not expect fruit and seeds from them. It would not be impossible, however, that flowers of other plant families which are provided with a large number of stamens might behave differently. It might happen, for example, that only *some* of the stamens would be changed into petals by the gall-mites, and that the carpels would remain capable of fertilization. If on such plants fruits and seeds capable of germination should ripen, the latter might perhaps produce plants with completely and half double flowers. This would be explained by supposing that the alteration undergone by the protoplasm of the cells in the outer part of the flower had extended to the inner, especially to the ovules and seeds, and further to the plants proceeding from these seeds. I would therefore not undertake to state that the Stocks (*Matthiola annua* and *incana*), the Wallflower (*Cheiranthus Cheiri*), the Pinks (*Dianthus Caryophyllus*, *plumarius*, &c.), the Poppies (*Papaver Rhæas* and *somniferum*), various Ranunculaceæ (*Delphinium*, *Pæonia*, *Ranunculus*), and many other plants which have long been cultivated in gardens with semi-double flowers, and which produce such flowers when propagated by seeds, had not gained this characteristic in the first place by the influence of gall-mites. It is less probable, though not beyond the range of possibility, that by the grafting of Hawthorn branches whose uppermost leaves have been deeply segmented by the influence of the gall-gnat *Cecidomyia Cratægi*, a Hawthorn bush might be produced which would exhibit these deep segmentations and slits on all its foliage. However, these last remarks are the merest suppositions; at present we have not the data on which to base any definite conclusions.

THE GENESIS OF NEW FORMS AS A RESULT OF CROSSING.

The aim of agriculturalists has always been so to cultivate their land as to rear plants likely to grow luxuriantly, to bear good fruit, and thus to afford an abundant harvest in return for their pains. Gardeners similarly have made it their endeavour to produce from wild plants races whose flowers are superior to those of the ancestral stock in form, colour, and scent; and the results of their labours are the delight and admiration of all lovers of beauty. In both cases the idea has been to perfect and "ennoble", and the means adopted have been successful to a degree calculated to amaze anyone who studies the history of cultivated plants with attention. The methods which led to these results have not always been deliber-

ately adopted, nor have they depended on scientific researches. On the contrary, chance observations made by growers in the course of their dealings with vegetable life as it occurs in nature have been the means of suggesting the first unaided attempts to make crops more productive, fruits and vegetables more palatable, and flowering-plants more pleasing to the eye.

The most important method adopted has been the artificial crossing of the species which are brought under cultivation. When we consider that, from time immemorial, Chinese and Japanese gardeners have produced Asters, Chrysanthemums, Camellias, Pinks, Peonies, and Roses, of which the majority are the results of crossing, we may assume with certainty that the practice of dusting flowers of one species with the pollen of another species first came into use in those countries. It is true that in Europe the contrivance was known to rose-growers at the time of the Roman Empire, but it was not employed on an extensive scale till the seventeenth century, when the fashion for breeding Tulips and Auriculas became the rage. The gardeners of that day still made a great secret of their mode of procedure, and it was not till the latter half of the eighteenth century that the production of new forms of plants by the aid of artificial crossing was carried on at all generally. For some decades the rearing of these new forms, which are called *hybrids*, has been one of the most important parts of a gardener's duties, and we shall not exaggerate if we put the number of hybrids hitherto produced in gardens in the course of the nineteenth century at 10,000. Many hybrids which were great favourites only a short time ago have disappeared from our gardens and have been replaced by others. As in so many other matters, the fashion changes; new forms are in constant request, and horticulturists endeavour to meet the demand by introducing wild plants from the most various regions and crossing them with those already under cultivation. It is now no longer uncommon for gardeners, in advertising some plant which has been brought from distant parts, to recommend it to the trade, not on the ground of its own beauty, but because it possesses flowers of an exceptional colour or leaves of a peculiar cut, and will therefore, in all probability, if crossed with other species, yield handsome new hybrids. Rose-growers always welcome the discovery of any instance of variation in the Wild Rose as an important event, because, by crossing this Rose with others, they are able to produce a large number of new forms, and there is always the chance that one or other of them may find favour with the public. On an average, 60 newly-bred Roses come into the market yearly; in the year 1889 the number even amounted to 115! A Rose cultivator at Meidling, near Vienna, grows in his garden nearly 4200 different kinds of Rose, and yet he is still far from possessing all the forms which have been produced in recent times (chiefly by French growers) by crossing one with another. According to his estimate, the number of Tea and Indian Roses alone is nearly 1400, and the total number of all the different Roses which the trade has produced up to the present day amounts to 6400.

The plant-forms which are called into existence by the operation of crossing are, in the case of Roses, reproduced largely by means of brood-bodies (cuttings and

layers) as well as by budding and grafting (see vol. i. p. 213); but the *first origin* of the new forms is always to be traced to crossing. This statement applies also to many other plants of which gardeners have taken possession, and especially to cases where propagation by seed requires more time and trouble than multiplication of brood-bodies. The kinds of Tulip, Gladiolus, and Lily produced by crossing are propagated most easily by means of bulbs, and the tuberous Begonias, Dahlias, and Gesneraceæ by tubers, whilst Pinks, Pelargoniums, Cactuses, and many others are most rapidly reproduced by cuttings. Moreover, these methods ensure the preservation of the peculiarities of the new forms unchanged, and such perpetuation of characteristics would be much more difficult to achieve if the plants were propagated by means of seeds. On the other hand, a number of new forms which have originated as the results of crosses effected in gardens, such as those of *Petunia*, *Portulaca*, and *Viola*, are reproduced with less trouble and greater rapidity by seeds, and that method is in such cases preferred to the cultivation of brood-bodies.

The statement that new forms of plants are bred originally in gardens by any other method than that of crossing is incorrect; it is sometimes made in ignorance, but sometimes also with the intention of deceiving. In former times gardeners believed that, in order to produce new forms, it was sufficient to plant different species in close proximity to one another. The idea was that if the seeds of such plants were taken and sown in good soil, there would always be found amongst the seedlings a few forms differing from the parent; these were to be selected for especial care in cultivation, and were to be treated as starting-points of new forms. The gardeners who acted on this assumption had not, it is true, themselves crossed the flowers; and if this was all they meant, there was no falsehood in the statement. The operation of crossing was, however, performed without their knowledge by hive- and humble-bees and other insects, and the planting together of the different species was only of advantage inasmuch as it facilitated the conveyance of pollen from one species to the stigmas of another. A celebrated grower of the old school once assured me, in all seriousness, that he did not himself cross the plants he reared, but that he had repeatedly observed that early in the morning, soon after a flower opened, it put forth infinitesimally fine threads which radiated in all directions and reached across to the flowers of other plants, forming in a short time a web like that of a spider! I would not have mentioned this statement were it not for the importance of pointing out the unreliable character of so many of the statements made by gardeners, especially in the past; and I repeat that the person responsible for the above communication is a well-known and much-esteemed horticulturalist. Gross inventions such as the above would, of course, be at once seen through and rejected by any thoughtful man; nevertheless, in some instances, reports of growers, likewise untrue or inaccurate, but not bearing the stamp of improbability so plainly upon the face of them, have been credited and have even found their way into books, particularly into those whose authors have omitted to confirm the reports by watching the garden-experiments from beginning to end themselves. The statements are then not infrequently quoted as "results obtained

by trustworthy experiments made by gardeners" and relied upon for the foundation of "laws based upon facts"; theories are then built up upon them, and are copied from one book to another. It becomes very difficult afterwards to get rid of such propositions, especially if they afford support to the hypotheses of distinguished *savants*.

An instructive example of the kind of thing referred to is afforded by the following statement which for a long time obtained currency in works on Botany: "Hybrids resulting from the crossing of two species exhibit two forms, in each case, according as the pollen employed in generating them belongs to the one or to the other species." There are, of course, two ways in which a pair of species, which may be represented by the letters A and B, may be crossed. In one case the pollen from A is transferred to the stigma in B, whilst in the other case the pollen is taken from B and transferred to the stigma in A. Now, it has been asserted that it is possible to determine from the form of the hybrid which of the two parent-species supplied the pollen. The hybrid is said to resemble that parent more closely from which the pollen was derived so far as its flowers are concerned, but to show greater affinity to the fertilized stock in respect of its foliage. This is, however, absolutely untrue. All careful experiments made without prejudice have pointed to the conclusion that it makes no difference to the forms, either of the leaves or of the flowers, whether the pollen has been taken from the one parent-species or from the other. Besides this, in most instances the approximation of the hybrid-form to one or the other stock affects all parts of the hybrid plant in an equal degree, and not the flowers or the foliage only. In the rare cases where a hybrid has flowers more like those of one parent and leaves more like those of the other, it is just as likely for one stock as the other to have yielded the pollen used for the cross.

But it would be a thankless task to attempt to correct all the hasty, careless, and erroneous statements, past and present, and it will probably be of greater utility to give a general survey of what has been ascertained concerning the form and temperament of hybrids by impartial observers who have taken into account all the concurrent circumstances, and have allowed for the sources of error incidental to the experiments.

The formation of a hybrid plant presupposes two stock-plants as parents which have different properties and characters. A cross must take place between the two—that is to say, the stigma of the one must be dusted with pollen from the other; the pollen must put forth pollen-tubes and an effectual union between spermatoplasm and ooplasm must be effected. For the sake of brevity, the plant from which the pollen, and therefore also the spermatoplasm, is derived is called the paternal stock or father-plant, and that which has its stigma dusted and its ooplasm fertilized is called the maternal stock or mother-plant. As a plant's external marks and characteristics, which are perceptible to our senses, are an expression of its internal organization and of the specific constitution of its protoplasm, it may be assumed that the plant-individual which owes its existence to the union of two protoplasts

of different constitutions possesses marks and attributes, some of which are characteristic of the father and others of the mother. As a matter of fact, the individuals which growers call by the various names of hybrids, mongrels, and bastards answer to this supposition. Some of their attributes and external characters are derived from the paternal, some from the maternal stock. If the relative admixture of the two stocks were to be determined in the case of a hybrid by summing up the characteristics transmitted from each source, the share of each parent would in many cases be found to be a half. In such a case it is usual to say that the hybrid is a mean between its parents. Examples are afforded by *Geum hybridum*, which originates from crossing *Geum montanum* and *G. rivale*, *Hieracium stoloniflorum*, derived from *Hieracium aurantiacum* and *H. pilosellaeforme*, and *Nuphar intermedium*, a cross between *Nuphar luteum* and *N. pumilum*. But it also happens sometimes that the proportion of characters inherited by a hybrid from one of the parent-stocks amounts to about two-thirds, leaving only one-third as the proportion inherited from the other, and in that case the hybrid is said to exhibit an approximation to one of the parent-species. The Saxifrage hybrids are very instructive examples of this class. The stigmas in a flower of *Saxifraga aizoides* were dusted with the pollen of *S. caesia*. Fertilization was successfully effected, and a capsule containing fertile seeds came to maturity. The plants reared from these seeds resembled in some cases the intermediate form described by Botanists under the name of *Saxifraga patens*; others approximated more closely to the paternal stock, and a third group to the maternal stock. A similar result was obtained by crossing a flower of *Saxifraga aizoides* with the pollen of *S. mutata*. From seeds of the same capsule were produced two different kinds of hybrid, of which one was intermediate between the parents (*Saxifraga Hausmanni*), whilst the other (*Saxifraga inclinata*) approximated more closely to *S. mutata*. These experiments point to the conclusion that the share which each parent has in the form of a hybrid depends upon the quantity of its spermatoplasm or ooplasm, as the case may be, used in the production of the seedling relatively to the quantity derived from the other parent; and in the case of hybrids issuing from the same fruit we are forced to suppose that the variability of the degree in which a particular form is inherited is caused by the existence of quantitative differences between the several spermatoplasmic and ooplasmic nuclei (or cells) which coalesce in pairs in the interior of the same ovary.

Important evidence in support of this supposition is derived from experiments made in connection with the crossing of various composites of the Thistle genus (*Cirsium*). In these plants each ovary contains a single ovule only, and therefore each fruit can only produce a single individual. On the other hand, each capitulum is composed of a large number of florets, and when a head is in full bloom nearly a hundred mature stigmas project from it in close proximity to one another. If pollen from another species is transferred by means of a paint-brush on to these stigmas, wholesale crossing, so to speak, ensues; and it may be confidently expected that a proportion of these simultaneous crosses will be effectual. The harvest of fruit

from the capitula selected for the experiment was not, it is true, very plentiful, but some fruits invariably came to maturity. If these one-seeded fruits, all of which have originated at the same time and under similar conditions, are sown, the individuals produced from them are but seldom like one another. The attributes and external marks of the paternal and maternal stocks respectively are in some represented in the proportion of about 2:1, in others in the proportion of 1:2, and in a third class in practically equal proportions; cases are even known where four, five, or more distinct forms of hybrid have developed from the fruits of a single capitulum. I found the most striking differences amongst the hybrids obtained by crossing a capitulum of *Cirsium oleraceum* with the pollen from a capitulum of *Cirsium heterophyllum*. Those produced by crossing a head of *Cirsium Pannonicum* with pollen from a head of *Cirsium Erisithales* were scarcely less conspicuously diverse. As it must be presumed that the spermatoplasm and ooplasm—or rather the spermatoplasmic and ooplasmic nuclei—which have been formed in the adjacent florets of a capitulum are alike in composition and ultimate structure, the variety of the hybrids springing from such florets must depend solely on the relation between the masses of ooplasm and spermatoplasm respectively which coalesce in a flower, and the ratio between these masses must be in the one case 1:2, in a second 1:1, and in a third 2:1. Of course these ratios give but an approximate measure of the degree in which each parent has participated in the generation of the intermediate forms. Where five kinds of intermediate forms occur the series would be approximately represented by the ratios 1:4, 2:3, 1:1, 3:2, and 4:1. The first time flowers of a head of *Cirsium Erisithales* were crossed with pollen from *Cirsium palustre* they produced two different forms of hybrid, one of which approximated to the paternal, the other to the maternal stock; but no form exactly midway between the two parent-stocks was obtained. A second trial of the same experiment resulted in the production of a single form which did occupy this intermediate position. These observations show that there is no definite law governing the form of hybrids; one might even say that irregularity is here the rule. On one occasion all the individuals which are the result of a cross between two species are alike, on another occasion they constitute more or less numerous links in a chain of intermediate forms.

Hybrids which do not stand midway between the parent-species but approximate to one or other of them are called *goneoclinic* (*γονεὺς*=parent, *κλίνω*=I lean). That such hybrids may arise from a first cross is established beyond question by the experiments above recorded; but there is also another process whereby they are produced, and that is the crossing of a hybrid with one of its parent-stocks. These crosses are effected in great numbers, and all observers agree that in general the results are better in such cases than where two species are crossed; that is to say, if a hybrid's stigmas are dusted with the pollen of one of the parent-species a larger number of fertile seeds may be looked for than if the plants crossed were of distinct species. The individuals resulting from the cross of a hybrid with one of the parent-stocks also occupy, as might be expected, a position as regards marks and attributes

intermediate between their progenitors; here again, however, forms are not always alike, and sometimes several intermediate forms make their appearance. If the hybrid derived from *Cirsium Erisithales* and *C. Pannonicum*, which inherits equally from both parents, be crossed with pollen from *Cirsium Erisithales*, the resulting individuals have a stronger resemblance to the latter species and are instances of goneoclinic hybrids. But when *Cirsium Erisithales* and *C. Pannonicum* are crossed for a first time hybrids are also produced which are not exactly midway between the parents but are more like *C. Erisithales*. These naturally resemble the goneoclinic hybrid derived from crossing the offspring of *C. Erisithales* and *C. Pannonicum* with *C. Erisithales*, and if one were not in a position to follow the history of the origin of the hybrid in question its characteristics alone would not furnish sufficient data for a judgment as to the mode of production of the goneoclinic hybrid.

Hybrids which are the offspring indirectly of three different species are called ternary hybrids. The word "indirectly" must be specially emphasized here, lest the reader should fall into the error of supposing it to be possible that pollen-tubes from two or more species should simultaneously fertilize a single ovule. Such an occurrence never happens, not even if a mixture of pollen belonging to two or more different species be placed upon the stigma of a particular flower. On the other hand, it has been ascertained by numerous experiments that if the hybrid-offspring of two species is crossed with the pollen of a third species, or *vice versa*, another hybrid is produced. Thus, for instance, if the hybrid of *Linaria genistifolia* and *L. purpurea* is crossed with the pollen of *L. striata* the result is a ternary hybrid. In one experiment the stigmas in a capitulum of *Cirsium Linkianum* (the hybrid offspring of *C. Erisithales* and *C. Pannonicum*) were dusted with pollen taken from *C. palustre*. A considerable number of fruits ripened, and the hybrids which arose from them were ternary hybrids, exhibiting marks and characteristics of *C. Erisithales*, *C. Pannonicum*, and *C. palustre* respectively. These hybrids, moreover, were not all alike; some of them bore striking resemblance to *Cirsium aquilonare*, the hybrid produced by crossing *C. palustre* and *C. Pannonicum*, and exhibited very few of the peculiarities of *C. Erisithales*, whilst other individuals were extremely like *Cirsium ochroleucum*, the hybrid obtained by crossing *C. Erisithales* and *C. palustre*, and only showed slight indications of its relation to *C. Pannonicum*. Growers of garden-flowers have achieved great success in producing ornamental ternary hybrids in a number of genera (*Achimenes*, *Begonia*, *Dianthus*, *Gladiolus*, &c.). Ternary hybrids of various Willows are also met with in gardens; one of these is obtained by crossing *Salix Cremensis*, a hybrid of *Salix Caprea* and *S. daphnoides*, with *S. viminalis*, another by crossing *Salix Wichurae* (the hybrid-product of *S. incana* and *S. purpurea*) with *S. cinerea*, and so forth. Willows have been also used for the prosecution of still further experiments. The crossing of two hybrids of different parentage on both sides resulted in the genesis of hybrids combining four species of Willow. Indeed, six different species of Willow have on one occasion been combined by successive crossing—Wichura having

succeeded in producing in Breslau a compound hybrid in which were united *Salix Caprea*, *S. daphnoides*, *S. Lapponum*, *S. purpurea*, *S. Silesiaca*, and *S. viminalis*.

It need hardly be said that the characteristics of the six ancestral species in such a case as that of the last-mentioned hybrid are not easily identified. Even where a hybrid is the offspring of a single cross between two species it is not always easy to determine its origin from its external appearance, and in the absence of any knowledge of the history of its production. The characteristics of the parent-stocks are not combined in all hybrids according to a single definite rule. Sometimes the combination seems to amount to a complete *fusion*, so that the form produced might be compared to an alloy of two metals. Very often a new form is generated which combines in a definite geometrical ratio the characteristics of the parents in respect of the position and direction as well as the shape and size of its separate parts. In that case there is said to be a union of the parental characters. The structural characters of both stocks are represented unmodified, but are so closely bound together as to suggest a composite crystal founded upon two different crystalline forms. Just as in definite combinations of crystals the faces of one component form are dominant, and determine the general aspect in one case and those of the other component form in another case, so in many hybrid plants sometimes the attributes of the one parent, sometimes those of the other, are most conspicuously reproduced. Other hybrids again are analogous to combinations in which both crystalline forms are equally represented. Again, in addition to the above classes of hybrids wherein the parental characters are either completely merged together or intimately united there are many cases where those characteristics are present almost unchanged, and subsist side by side like the particles of a rock. The most common case of this *mixture* or juxtaposition of properties occurs where the hybrid displays hairs, glands, or prickles of two forms interspersed together, one of which is identical with the form of the structure in question exhibited by the maternal stock, whilst the other has been inherited unchanged from the paternal stock. Or, one part of the hybrid's flower may be coloured like one parent and another like the other parent. Hybrids are also known in which the foliage is almost indistinguishable from that of one parental stock whilst the flowers are like those of the other, so that at first sight a hybrid of the kind looks as if it were a plant of the former species with flowers of the second species affixed to it for a joke. On closer inspection some slight differences may be perceived between the leaves and flowers of the hybrid and those of the parent species respectively, but this does not alter the fact that hybrids exist whose leaves resemble far more closely those of one parent, whilst their flowers are more like those of the other. Probably it was the occurrence of such a hybrid which suggested the proposition referred to on p. 557 that in the product of a cross between two species the flowers reveal the paternal and the foliage the maternal stock. But this statement is incorrect, as was said before, for some hybrids approximate to the maternal stock in respect of their flowers, and to the paternal stock in respect of their leaves.

Of the three ways in which the parental characters may be combined in a

hybrid—i.e. by fusion, by union, or by mixture—one alone sometimes prevails in all the parts; but usually, on the contrary, there is an incalculable degree of variation in this connection. There are, for example, Rose hybrids in which the outline of the leaves exhibits a union, the colour of the flowers a fusion, and the hairs a mixture of the corresponding characters in the parents.

A brief account will now be given of a few examples to illustrate the manner in which the combination of parental characters in a hybrid is manifested throughout the structure of the plant and particularly in the forms of the stems, leaves, and flowers, and in those of thorns, bristles, hairs, and other epidermal appendages. The species of Willow known as *Salix Caprea* grows in the form of a little tree, with thick, straight, erect branches, each of which bears about 25 leaves; *Salix repens*, on the other hand, is a low shrub with a procumbent stem and slender, rod-like branches ascending in curves from it, and each bearing about 40 leaves. The hybrid of these two is a small tree with a bent stem and ascending branches, which in length, thickness, curvature, and direction are intermediate between the *Salix Caprea* and *Salix repens*, and which are furnished with some 30 leaves apiece. Again, the foliage-leaves of *Prunella vulgaris* have their margins entire, whilst those of *P. laciniata* are deeply cut, and their hybrid *Prunella intermedia* has lobed leaves. The leaves of *Potentilla sterilis* (or *P. Fragariastrum*) possess three leaflets, each leaflet being furnished on either side with from four to five serrate indentations. The leaves of *Potentilla micrantha* likewise possess three leaflets, but each leaflet has from seven to ten serrate teeth on each side. In the hybrid of these two species the leaflets have from six to eight indentations on each side. The shape of the leaf is, as is well known, intimately connected with the course, ramification, and disposition of the bundles called nerves. Now, if the net-work of strands in the leaves of the parent-species is compared with that in the leaves of the hybrid, it is astonishing to find how the union of the two systems may be traced in the minutest details. No group of plants lends itself better to this sort of investigation than the Willows. Even if a single leaf of the hybrid offspring of two species of Willow is submitted for inspection, it is possible in most cases to determine, from the number and distribution of the nerves, the identities of both its parents. *Salix purpurea* produces one hybrid when crossed with *Salix grandifolia*, and a second when crossed with *Salix Caprea*. *Salix grandifolia* has twice as many lateral nerves in each leaf as *Salix Caprea*, and this difference is reproduced in the corresponding hybrids, whose leaves in all other respects resemble one another closely.

The involucreal leaves of Composites are well known to be extremely diverse in shape, and systematic Botanists have always attributed great importance in the discrimination of species to the size, shape, and margination of these leaves and to the peculiar appendages at their apices. Now, the hybrids of Composites not infrequently have involucreal leaves which differ widely from the forms characteristic of the parent-stocks. Thus, for instance, each leaf of the involucre in a capitulum of *Centaurea rupestris* terminates in a long yellow prickle, whilst the

corresponding structure in *Centaurea Scabiosa* is bordered by a broad, membranous, fringe-like edge of a dark-brown colour. In *Centaurea sordida* (Graftana), the hybrid offspring of these two species, each involucre leaf is edged with a narrow, light-brown membranous and fringed border, and terminates in a short yellowish prickle. A very instructive example of the union of parental characters affecting all the different parts of the floral region is afforded also by the Labiate *Marrubium remotum*, which is produced by crossing *Marrubium peregrinum* and *M. vulgare*. The small tuft-like inflorescences in the leaf-axils of *Marrubium peregrinum* include from 10 to 18 flowers, those of *M. vulgare* from 4 to 5, and those of the hybrid *M. remotum* from 5 to 10. The calyx of *M. peregrinum* is grey and covered with felted hairs, and its margin is provided with five large subulate teeth which terminate in straight points. The calyx of *M. vulgare* is green and sparsely clothed with hairs, and its edge has ten small teeth which terminate in stiff reflexed points like hooks. Five of these teeth are rather longer than the rest. The calyx of *M. remotum* is greyish-green and clothed with a loose felt; its edge is furnished with five big subulate teeth which terminate in stiff out-curved points, and have from two to five very small teeth interspersed between them. The three lobes of the under-lip of the corolla are almost of equal length in *Marrubium peregrinum*, whilst in *M. vulgare* the middle lobe is three times as long as the two lateral lobes. In the hybrid *Marrubium remotum* the middle lobe of the lower lip is half as long again as the lateral lobes. An excellent example is also afforded by *Dianthus Œnipontanus*, a hybrid Pink resulting from a cross between *Dianthus alpinus* and *D. superbus*. In *D. alpinus* the bract-like scales at the base of the calyx are almost as long as the tube of the calyx itself, whilst in *D. superbus* their relative length is only a quarter or a third; in the hybrid *D. Œnipontanus* these bracts are half as long as the tube. The petals of *D. alpinus* have broad laminæ beset at the margin with short triangular teeth, those of *D. superbus* have their laminæ slit up into a number of narrow strips, and those of *D. Œnipontanus* have deeply-incised laminæ, the margins being divided into linear segments. The dimensions of the various parts of the flower in a hybrid also exhibit in most cases a combination of the corresponding parental characteristics. Thus, for instance, the perianth of the Orchid *Gymnadenia conopsea* has a long spur—that is to say, the segment of the perianth known as the labellum is produced backwards into a saccate protuberance supposed to resemble a spur, and this portion of the petal in *Gymnadenia conopsea* is 15 mm. in length. In *Nigritella nigra*, on the other hand, the spur is very short, measuring about 2 mm. The hybrid of these two Orchids, *Nigritella suaveolens*, has a spur varying from 5 to 7 mm. in length. In Willow hybrids the number of stamens in each flower of the hybrid is invariably between the corresponding numbers in the two parent-species. For example, the number of stamens in a flower of *Salix alba* is 2, in *Salix pentandra* 5–12, and in their hybrid *Salix Ehrhartiana* 3–4.

The cellular structures produced from the epidermis of the stem and leaves which are differentiated as hairs, bristles, scales, glands, &c., and are classed together

under the name of investments (*indumentum*), are very constant characters in most species of plants. The occurrence of stellate hairs, in particular, is looked upon by systematic Botanists as an important point in assisting them to distinguish between similar species, and so also is the presence of glandular hairs composed of simple rows of cells, and terminating in globular bladders full of ethereal oils. Hybrids exhibit the most varied combinations of the indumenta of their parents. In the majority of cases the characteristics of the two stocks in this respect are mixed, but less frequently are they united, and in the latter case the shape, size, and number of hairs, bristles, scales, and glands are intermediate between those of the same appendages in the two parent-species. The Lungwort genus (*Pulmonaria*), which has a special tendency to hybridization, includes only a few species, but each one may be recognized by the nature of its indumentum. Thus, *Pulmonaria officinalis* is distinguished by the thousands of short unicellular prickly hairs, scarcely perceptible to the naked eye, which are interspersed amongst the long scattered bristles on the upper surfaces of the leaves. In *Pulmonaria angustifolia* the leaves are destitute of these minute prickles, but bear on their upper surface a more abundant quantity of straight appressed bristles of equal length. The leaves of the hybrid derived from the two preceding species, viz. *Pulmonaria hybrida*, are richly supplied with long bristles, and interspersed amongst these may be seen a large number of shorter bristles which are about two or three times as long as the prickly hairs of *Pulmonaria officinalis*. A very instructive example is also afforded by the hybrid *Rhododendron intermedium*, which is easily produced by crossing the two Alpine-Roses (*Rhododendron ferrugineum* and *Rhododendron hirsutum*). The upper faces of the leaves of *R. ferrugineum* are dark-green, smooth, and shining, whilst their backs are rusty and dull owing to the presence of a dense crowd of tiny scales. The margins are not ciliate. The leaves of *R. hirsutum* are light-green and beset with scattered whitish glands (see vol. i. p. 232, figs. 54^b and 54^c), and their margins are fringed with long hairs. In *Rhododendron intermedium* both kinds of epidermal appendage are displayed side by side. The under surface of the leaf is furnished with brown scales, though not so profusely as in *Rhododendron ferrugineum*, and its edge is fringed with hairs, but not so thickly as in *R. hirsutum*. The same sort of thing occurs in Roses, Cinquefoils, Blackberries, Drabas, Hawkweeds, and many other plants. Where one parent Rose bears only non-glandular and the other only glandular hairs the hybrid is sure to be clothed with a mixture of the two kinds of hairs. Several species of Cinquefoil (*Potentilla*) have stellate or tufted hairs, whilst others are entirely free from them and bear none but simple hairs on their leaves. In hybrids derived from two of these species—one with compound and the other with simple hairs—stellate or fasciculated hairs are invariably intermixed with a large number of simple hairs. A few species of the perennial Whitlow-grasses (*Draba*), which are indigenous to mountainous districts in Central Europe, have rectilinear anvil-shaped hairs, whilst others have three- or four-rayed stellate hairs. In the hybrids which spring from these different species rectilinear and stellate hairs grow together on the same leaf. If the hairs of two parent-species are of the

same form but of unequal length, those of their hybrid offspring have a length which corresponds approximately to the mean between the lengths in the parent-species. Thus the length of the hairs on the backs of the leaves is 0.3 mm. in *Salix aurita*, 1.2 mm. in *Salix repens*, and 0.6 mm. in their hybrid *Salix plicata*. The hairs in *Salix Caprea* measure 0.8 mm., in *Salix viminalis* 0.3 mm., and in *Salix acuminata*, their offspring, 0.5 mm. Whenever one stock is glabrous and the other hairy, one may be quite sure that the corresponding parts of their hybrid will be furnished with hairs, but less profusely than the parent-species from which that particular characteristic is derived. This is the case, for instance, with *Primula Sturii*, the hybrid produced by crossing the glabrous *Primula minima* with *Primula villosa*, which has glandular hairs. The leaves of the latter are thickly covered with these hairs, which vary from 0.1 mm. to 1 mm. in length, and *Primula Sturii* has scattered glandular hairs which measure 0.3 mm. The hybrids obtained by crossing the Purple Willow (*Salix purpurea*) with the Common Osier (*Salix viminalis*) are distinguished by Botanists into two sections, one of which—*Salix rubra*—approximates to the Purple Willow and the other—*Salix elæagnifolia*—to the Common Osier. The leaves of the Purple Willow when mature are glabrous at the back, those of the Common Osier have small glistening hairs lying appressed to their under surfaces, parallel to the lateral nerves, and measuring 0.3 mm. There are about 1800 of these hairs on a square millimetre. The hairs of the hybrid *Salix elæagnifolia* are of the same length as those of *S. viminalis*, but there are only about 800 of them to the square millimetre, whilst the hairs of the hybrid *Salix rubra* are somewhat shorter, and there are only 400 to the square millimetre.

Recently the discovery has been made by Wettstein that the form and disposition of the cells and tissues in hybrids is also a combination of the corresponding characteristics in the parent-species. The various species of the Pine genus (*Pinus*) may be distinguished with certainty by the anatomical structure of their needle-shaped leaves, in particular by the thickness of the epidermal cells, the number of the stone-cells lying beneath the epidermis, and the number of the resin-ducts. In the hybrids the anatomical characters of the parents in these respects are united, and the result is indeed often an exact arithmetic mean between the two. Thus a needle of the Scotch Pine (*Pinus sylvestris*) contains from 6 to 10 resin-ducts, that of the Mountain Pine, *Pinus Mughus* (*montana*), contains from 3 to 5, and that of the hybrid offspring of the two from 5 to 7 such ducts. The Junipers (*Juniperus*) afford a similar instance. In their case the leaves are distinguished by the various thickness and length of the layer of sclerotic-cells which covers the back of each leaf, by the width of the resin-duct running through the middle of the leaf, and by the number of the cells encasing that duct. In the hybrids, such as *Juniperus Kanitzii*, which is produced by crossing *Juniperus communis* and *J. sabinoides*, there is evidently a union of the parental attributes in the corresponding cellular structures in the leaves. It has also been shown by Hildebrand that in the Wood-Sorrel (*Oxalis*) hybrids also the anatomical characters of the parents are united, but by far the most comprehensive study which has

been made in recent times into the minute structure of plant-hybrids is by Macfarlane. He selected a number of hybrids, and worked through their anatomy from base to apex in the most painstaking manner. He dealt with roots, stems, leaves, and the various portions of the flower, always comparing their various tissues (both as regards size, form, and distribution) with those of their parent-forms. And his result is to confirm what has been written above, though it is obvious he had never read these pages. Amongst the more interesting of his results may be mentioned those on starch-grains. Of course in a great many of the parent-forms uniting to form a hybrid there is no recognizable difference in the size or structure of the starch-grains. But in the genus *Hedychium* (belonging to the family Zingiberaceæ) exceptions to this rule were found. Thus, those of *Hedychium Sadlerianum* are intermediate in form and size between those of its two parents, *H. Gardnerianum* and *H. coronarium*; and those of a hybrid between *H. elatum* and *H. coronarium* exhibited similar intermediate characters.

It is important to note also that the aromatic substances and colouring matters produced in the cells of a hybrid are inherited partly from the maternal, and partly from the paternal stock. As we have several times already had occasion to mention, the various species of the Rose genus may be recognized at once by their peculiar scent. The perfume of *Rosa Centifolia* is the one which in particular is understood by the rose-scent, but it is very different from that of *Rosa alpina*, and the latter in its turn is unlike any of the scents emitted by *Rosa arvensis*, *R. Gallica*, *R. Indica*, &c. *Rosa Nasterana* has a scent strongly resembling that of Pinks, whilst *Rosa lutea* and *R. punica* are notorious for their disagreeable smell. Now the hybrid Roses emit odours in which the scents of the parent-species are merged together in a great variety of ways. Usually the scent of one stock predominates, and there is only a suggestion of the other. Sometimes, however, an entirely new scent is evolved from the fusion of the two, as is the case, for instance (according to Macfarlane), in *Hedychium Sadlerianum*, the hybrid between *H. Gardnerianum* and *H. coronarium*; and, again, in other cases, one of the component odours is intensified and the other is extinguished. The same statement applies to the aromatic substances to which the scent of the foliage is due. The hybrids of *Rosa glutinosa*, *Rosa rubiginosa*, and *R. rugosa*, with *Rosa Gallica* and *R. Centifolia*, are very interesting in this connection. The aromatic substances which are contained in fruits and excite our nerves of taste are also inherited, partly from the maternal and partly from the paternal stock. Owing, however, to the difficulty of naming the various sensations of smell and taste it is of little use to discuss the subject more fully.

As regards the colouring-matters reproduced in hybrids the first point to notice is that in cases where the foliage is of different shades of green in the parent-species the leaves of the hybrid exhibit a shade intermediate between the two. Conspicuous instances of this are afforded by the hybrid Willows derived from *Salix nigricans* and *S. purpurea*. In both these species the foliage becomes *black* when it withers, and this characteristic is transmitted, though not in its full strength, to the hybrids

which *S. nigricans* and *S. purpurea* form with other Willows whose foliage turns brown when it dries up. The colour of the flowers in hybrids is usually the result of a *fusion* of the colours in the parent-species; less frequently it is a *mixture* of the original colours. The cases of fusion occur especially amongst the hybrids of Orchids, Louseworts, Anemones, Pulsatillas, Medicagos, and Mulleins. If the tone of the red or blue petals in one parent-species is dull and in the other bright, the same colour reappears in the hybrid, but of a medium tone. Thus the colour of the petals in *Gymnadenia conopsea* is rose-red and in *Nigritella nigra* dark blood-red, whilst in their hybrid, *Nigritella suaveolens*, it is bright carmine. The corolla of *Pedicularis incarnata* is of a subdued carmine tint, and that of *P. recutita* of a dark reddish-brown, whilst their hybrid, *P. atrorubens*, has a dark purple corolla. Where the floral colour of one parent-species is white and that of the other a full yellow, red, or blue, the hybrid's flower usually exhibits a pale yellow, red, or blue coloration. The flowers of *Anemone nemorosa* are white, those of *A. ranunculoides* golden-yellow, and those of their hybrid, *A. intermedia*, sulphur-yellow. The colour of the flowers in a hybrid whose parents have yellow and violet, or blue flowers, respectively, is very remarkable. *Medicago media*, which is the hybrid offspring of the yellow-flowered *Medicago falcata*, and the blue-purple flowered *M. sativa* very often has green corollas. The hybrids (*Verbascum commutatum*, *V. rubiginosum*, *V. Schmidtii*, *V. versiflorum*, &c.) obtained by crossing the yellow-flowered Mulleins with *Verbascum phæniceum*, whose flowers are a conspicuous purple, all display a bright brown tint in their corollas. The colour in question is just the same as that which is produced by mixing gamboge with the purple prepared from carmine and indigo. Quite a different tint is exhibited by the corolla of *Verbascum pseudophæniceum*, the hybrid generated by crossing *V. Blattaria* and *V. phæniceum*. One of the parent-species (*V. Blattaria*) in this case has pale yellow and the other (*V. phæniceum*) violet-purple corollas, and in the hybrid (*V. pseudophæniceum*) the corolla is pale crimson. Nor are cases wanting in which hybrids have been produced from forms with red and blue flowers respectively. The brilliant scarlet-flowered *Delphinium nudicaule* has been crossed in the Edinburgh Botanic Garden with the dark blue-flowered *D. cashmirianum*, the hybrid product being of a lurid purple-red hue. Darwin obtained by crossing the red and blue Pimpernels (*Anagallis*) a progeny some of which were blue, some red, and some intermediate in colour. As a final instance of this colour-fusion may be cited the hybrid Pitcher-plant *Nepenthes Mastersiana*. This hybrid is produced from *N. sanguinea*, the pitchers of which are of large size and vary in colour from greenish-scarlet to crimson, and of *N. Kharsiana*, which bears long narrow pitchers, varying from yellowish-green to dull red-green. The hybrid (says Macfarlane) presents a corresponding latitude in colour effect, though on the average it is greenish-crimson.

The hybrids which originate from crosses between *Primula Auricula*, whose flower is all of one colour, and *Primula Carniolica*, *P. hirsuta*, *P. Oenensis*, *P. villosa*, &c., which have bi-coloured flowers, are also of great interest in this connection. *P. pubescens*, the hybrid produced by crossing *P. Auricula* and *P. hirsuta*,

is the stock from which the garden Auriculas are derived. The colour of the corolla in *P. Auricula* is a uniform golden-yellow excepting that at the throat, *i.e.* at the junction of the tube with the expanded limb, there is a floury efflorescence which, like that covering the calyx, pedicels, and bracts, is due to a peculiar modification of the epidermis. The corolla of *P. hirsuta* is bi-coloured; the segments of the limb are violet-red, whilst the throat is white. The two tints are sharply marked off from one another, and in consequence a white five-rayed star is seen in the middle of the flower. There is in this case no trace of a floury efflorescence. In the hybrid offspring of these two *Primulas* both the violet-red of the limb and the white of the throat are blended with yellow; the former exhibits a touch of brown, and in the middle of the flower is a pale-yellow star.

It is much less common for those floral colours which are inherited by a hybrid from the parent-species to be displayed in juxtaposition than in a blended condition. Since the time of the Roman Empire gardeners have crossed the red-flowered *Rosa Gallica* and *R. Damascena* with the white-flowered *Rosa alba* and obtained thereby hybrids in which the petals are striped and spotted longitudinally with red and white (so-called "York and Lancaster" roses). Similar cases occur amongst hybrid *Calceolarias*, *Pinks*, *Petunias*, and *Wood-Sorrels*, and instances of *Tulip* and *Iris* hybrids are also known where the perianths exhibit the two different colours of the parent-species side by side in streaks and patches. A hybrid of *Iris Florentina* and *I. Kochii* is especially deserving of notice. The perianth in *I. Florentina* is milk-white and that of *I. Kochii* is dark violet. The hybrid of these two species was first obtained in May, 1871, in the Botanic Garden at Innsbruck; one of the individual plants thus produced had two of the outer and one of the inner members of the perianth shaped like those of *I. Kochii* and of a deep violet colour, and one of the outer and two of the inner members shaped like those of *I. Florentina* and milky-white in colour. This arrangement of colours re-appeared year after year until in 1877 a single flower, in which the lower white members had some dark violet streaks widening out from the middle to the edge of the perianth also made its appearance. A second plant of the same hybrid developed flowers which only differed from those of *I. Florentina* in that a few of the white petals had dark violet streaks widening out towards the circumference. An equally noteworthy case is that of a hybrid reared in the Botanic Garden at Florence from *I. Germanica* and *I. sambucina*, of which a specimen was sent to me in 1872. One inferior and two superior perianth-members displayed on one half of their surfaces the colour and pattern peculiar to *I. sambucina*, and on the other half those characteristic of *I. Germanica*. The rest of the perianth could not be distinguished except by its smaller size from that of *Iris Germanica*.

It must not be supposed, however, that the presence of variegated stripes, patches, or speckles on petals is always an indication of hybridity. *Viola polychroma*, a very common Alpine species, not infrequently produces simultaneously two, three, or four open flowers, every one of which presents a different mixture of tints, and amongst plants of this species covering only a small patch of ground it

would be easy to find 100 blossoms with corollas differing from one another in the distribution of their colours and in the arrangements of the spots and streaks upon them. Similar phenomena are exhibited by *Iris pumila* and *Polygala amarella*. The flowers in *Polygala amarella* are equally blue and white or sprinkled with blue and white, and it is also no rare thing for plants to bear white flowers interspersed with a few which are sprinkled with blue. In the same way several species of *Anthyllis*, *Euphrasia*, *Galeopsis*, *Linaria*, *Melittis*, *Ophrys*, *Orchis*, *Saxifraga*, &c., exhibit considerable variation in the colours and markings of their petals, which yet is not to be attributed either to hybridization or to the influence of soil or climate. Reference must also be made here to the large number of species (already mentioned on p. 194) in which the floral coloration is by turns blue and white, red and white, blue and red, yellow and white, and so on. Heterochromatism, i.e. the change in the coloration and marking of petals, serves, in fact, in some plants as a specific character. Contrasting with these heterochromatic species are those with homochromatic flowers, which, as far as experience has shown, invariably present the same colour and pattern, and only exhibit a slight variation in the depth of the colour when subjected to the influence of light of varying degrees of intensity. *Iris Kochii* and *I. Florentina*, *Primula Auricula*, and *P. hirsuta*, together with other pairs of species referred to above as the progenitors of hybrids of special interest, belong to the category of plants possessing homochromatic flowers, and it is obvious that in the hybrid offspring of such plants the floral coloration would be an important sign of identity.

This will be the most convenient place in which to introduce a few words concerning the *Bizzaria* of Italian gardeners, and also concerning so-called *graft-hybrids*. The name of *Bizzaria* has been given by the Italians to an extremely curious Orange. Galesio (1839) states that this Orange-tree produces at the same time foliage, flowers, and fruit identical with the Bitter Orange (*Citrus Aurantium*) and with the Citron of Florence (*Citrus medica*), and likewise compound fruit, with the two kinds either blended together, both externally and internally, or segregated in various ways. In the fruits of the *Bizzaria* which I have seen, five longitudinal stripes of the colour of a Citron were interpolated in the fruit of the Orange. Other fruits were, on the whole, like Oranges, excepting as regarded an eighth of their mass, which in form, colour, and taste resembled a Citron, and was also peculiar for its extreme convexity. This anomalous segment stretched in the form of a light-coloured cushion from one pole of the spherical fruit to the other. Growers maintain that the *Bizzaria* is the result of a cross between *Citrus medica* and *Citrus Aurantium*, though the gardener who, in 1644, in Florence, raised this tree, declared it was a seedling which had been grafted, and after the graft had perished the stock sprouted and produced the *Bizzaria* (according to which account it would be a graft-hybrid). In other similar cases of *Citrus* hybrids, however, such as the Bergamot Orange, alleged to be a hybrid of the ordinary Lemon and the Bitter Orange, one finds the characteristics of the parent-species do not

reappear in juxtaposition (as in the *Bizzaria*), but are united or fused together. Whether the case of Bergamot Pears, which are striped green and yellow, and that of the half dark- and half light-coloured grapes, of which a few occur occasionally in otherwise ordinary bunches of the fruit, are to be looked upon as parallel phenomena to that of the *Bizzaria* must remain uncertain until it has been ascertained to what particular crosses of the various species of *Pyrus* and *Vitis* the innumerable Pear-trees and Vines now cultivated owe their origin.

Over and over again gardeners have asserted that hybrids may also be produced by budding and grafting, and in order to distinguish plants so arising from those which are the result of a cross (*i.e.* from true hybrids), they are called *graft-hybrids*. One of these plants, a Laburnum named *Cytisus Adami*, which exhibits a curious mixture of the characteristics of *Cytisus Laburnum* (the ordinary yellow Laburnum) and *Cytisus purpureus* in the same individual, has been the subject of lively discussion in scientific circles. It is indeed difficult to imagine anything more curious than a plant of *Cytisus Adami*. Most of the flowers derive their characters equally from both parent-forms; the calyx is not so thickly clad with silky hairs as in *C. Laburnum* nor so smooth as in *C. purpureus*, and the corollas are of a dirty-red colour, compounded of the purple of *C. purpureus* and the yellow of *C. Laburnum*. But the curious thing is that on many of the racemes a few blossoms of different appearance are interspersed amongst these red flowers, some having yellow corollas and silky-haired calices as in *C. Laburnum*, and others, still more remarkable, having half their petals like *C. purpureus* and half like *C. Laburnum*, or a third of their petals like *C. purpureus* and two-thirds like *C. Laburnum*, or some one of many other combinations. According to Schnittspahns, this anomalous form of *Cytisus* was first produced at Vitry, near Paris, in the year 1826, by a grower named Adam, who inserted a bud of *C. purpureus* into a stock of *C. Laburnum*. The shoot which sprang from the bud was not a pure branch of *C. purpureus*, but had characteristics derived both from *C. purpureus* and from *C. Laburnum*. Buds for propagating *C. Adami* were sent from Vitry to gardens all over Europe, and were in some cases inserted into stocks of *C. Laburnum*, and in other cases into stocks of *C. Jacquinianus* and *C. alpinus*. In many cases gardeners grafted buds of *C. purpureus* in addition to those of *C. Adami* on to the same stocks, and thus produced shrubs of most extraordinary appearance. Of the branches some resembled *C. Laburnum*, *C. Jacquinianus*, or *C. alpinus*, others *Cytisus Adami*, and others again *C. purpureus*; and amongst the racemes were many which bore the ordinary flowers of *C. Adami*, interspersed with a few blossoms of *C. Laburnum*, and others in whose flowers a mixture of the properties of *C. Laburnum* and *C. purpureus* was apparent. The fact of main interest, however, is that cuttings from Adam's original plant (the alleged graft-hybrid of *C. Laburnum* and *C. purpureus*) should bear not only flowers of an intermediate type (as might be looked for in a hybrid), but that on certain branches the flowers break back (or revert) to the pure form of one or other of the parents, or that a single flower should exhibit on one half the characters of one parent and

on the other those of the other parent. Thus the alleged graft-hybrid bears three distinct sorts of flowers, and often parti-coloured combinations of the two parent forms. The anatomical details of the tissues of the *Adami*-forms have been examined and compared with those of the two parent-forms by Macfarlane. It appears that the tissues show a remarkable mingling of the two parent-forms. In some the one, in others the other parent-form predominates. Though in the flowers (*i.e.* the pure *Adami*-flowers) the mingling is quite consistent with its being a well-balanced seed-hybrid, in the vegetative regions the strikingly diversified intermixture of tissues is unlike that met with in any seed-hybrid hitherto examined. It should be mentioned that where the *Adami*-plant bears *Laburnum* or *purpureus* shoots and flowers the anatomical characters of these shoots is identical with the normal *C. Laburnum* and *C. purpureus*, respectively. Finally the *Adami*-flowers never ripen seeds (the ovules being malformed), though when the parent-forms occur upon it they ripen fruit and seed.

As a general rule the relations of the graft to the substratum (or stock) are very different from those manifested in the case of Adam's experiment. The shoot developed from the ingrafted bud makes the same use of the substratum in which it is imbedded as a parasite makes of its host-plant (see vol. i. p. 213). It procures from the substratum a supply of "crude sap", and this material is absorbed and worked up by the protoplasts of the cells of the graft in the same way as the liquid substances of the soil which are sucked up by roots. It must be premised that those cells of the graft which take up the crude nutrient sap are adapted to their work in very much the same way as are the suction-cells of roots, that is to say, they are able to exercise a selective power, and only admit such substances as are good for the species to which the scion belongs. Any influence that the substratum might have on the graft could scarcely be other than such as would be exercised by soils of various composition. At the most we should expect variations in shape and colour, which have no permanence, and are not retained by the scion's posterity. As a matter of fact, if, for instance, cuttings are taken from an Apricot-tree and grafted on to various other *Amygdaleæ*, or are transferred from a Pear-tree to Quinces, White-thorns, and other *Pomaceæ*, they do not exhibit the slightest alteration in fruit, flowers, or foliage after entering into organic union with the stock. Again, when hybrid Roses produced by crossing are propagated by budding and grafting, the result is the same whatever species of Wild-rose is taken for the substratum or stock. In all the thousands of cases of propagation by these means none has been observed in which the stock has had any essential influence upon the form of the scion.

In 1876 and 1877 certain experiments were made in the Botanic Garden at Innsbruck on the genus *Iris*. They were suggested by the fact of the production of the hybrids of that genus already referred to, and consisted in grafting buds from the root-stock of one species of *Iris* on to that of another species of the same genus. The experiment was attended with perfect success, but the shoots and flowers developed from the ingrafted buds showed no trace of any influence on the

part of the substratum. Buds of *Iris Kochii* grafted on *I. Florentina* produced unaltered plants of *I. Kochii*, and buds of *I. Florentina* grafted on *I. Kochii* developed simply plants of *I. Florentina*. In the Botanical Garden at Vienna there is a male Ginkgo-tree (*Ginkgo biloba*) which, more than a hundred years ago, was the subject of an important experiment. When the tree was still quite small the bud of a female tree was grafted upon it by Jacquin, and a lateral branch was developed from this bud. What we have now is a mighty tree with a number of branches bearing male flowers, and one large branch bearing female flowers. The notable thing about the tree is that the grafted branch follows a course of development which is obviously different from that of the stock. Every year in the spring it puts forth foliage about fourteen days later than the male branches, and in the autumn its leaves are still green long after the rest have turned yellow and, for the most part, fallen off. From this instance we may infer that the shoots developed from the grafted bud adhere with the greatest tenacity even to individual characteristics, and do not suffer the substratum to affect them even in respect of their annual development.

These facts have of recent years led many people to the opinion that the genesis of graft-hybrids is simply a gardener's story, and that even the most famous of the supposed graft-hybrids—*Cytisus Adami*—does not owe its origin to budding, but to a cross between *Cytisus Laburnum* and *C. purpureus*. Still, in view of the curious mixing of the parent-characters in *Cytisus Adami*, as revealed by Macfarlane's investigations, it would perhaps be well to suspend our judgment. It is true that even in true seed-hybrids (e.g. the *Iris* hybrids mentioned on p. 568) a mixing (not a fusion) of the parental characters of the flowers was observed. Fresh observations in this field are wanted, directed especially with a view to showing whether or not the sum-total of the characters of *Cytisus Adami* are absolutely unique amongst hybrid-plants of whatsoever origin.

A further instance of the same nature may be mentioned, as it has been the subject of careful scientific investigation and experiment. In 1876 a Jerusalem Artichoke (*Helianthus tuberosus*) was grafted upon a Sunflower (*Helianthus annuus*) in the neighbourhood of Bristol, and it was alleged that as a consequence the Sunflower stock had acquired from the Artichoke the property of producing tubers on its subterranean portions. Quite lately a series of buds of the Artichoke were grafted on Sunflower stalks by Vöchting, and the results carefully followed. It was not found that the properties of the one were in any instance transmitted to the other, although scion and stock grew together in perfect harmony.

The importance of this subject is so great that I cannot refrain from trespassing for a moment on the domain of Zoology in order to refer to a case which shows that the animal world also sometimes affords instances of the characteristics of both parents being manifested in juxtaposition in their hybrid-offspring instead of being merged together or united in close combination. *Tetrao medius* is well known to be a hybrid produced by a crossing between the Black grouse (*Tetrao tetrix*) and the Capercaillie (*Tetrao Urogallus*). This hybrid is so common in Tyrol that the

poulterers in Innsbruck receive for sale on an average six specimens every year from huntsmen in the immediate neighbourhood. The plumage of some individual examples of *Tetrao medius* is curiously striped with alternate groups of feathers inherited from *T. tetrix* and *T. Urogallus* respectively. In 1879 a huntsman brought me from the remotest part of the Gschnitzthal in Tyrol a hen of *Tetrao medius* whose plumage exhibited a mixture of the feathers of *T. tetrix* and *T. Urogallus*, irregularly distributed in stripes and patches all over the body. The case of this hybrid affords valuable confirmation of the results of the experiments made on *Iris* hybrids, and there can no longer be any doubt of the fact that there are hybrids generated by crossing in which the parental characters reappear in juxtaposition.

In spite of all this, however, I should not like to deny the possibility of the existence of *graft-hybrids*, for there are certain considerations which tend to a contrary conclusion. In most cases the relation to the substratum of those cells of the ingrafted shoot or bud which take the crude nutrient sap from the stem of the stock-plant is just the same as that of a parasite's suckers; they are clearly marked off from the cells of the substratum and are not influenced thereby either in their shape or in their ultimate structure, whilst, conversely, no essential modification is undergone by the substratum through the presence of the graft. There is nothing, however, to exclude the possibility of a fusion between the protoplasmic contents of adjacent cells taking place at the spot where stock and graft unite, and the consequent development of a tissue which is composed of cells arising from a division of the cells containing the mixed protoplasts, and which unites the characteristic features of the tissues belonging to the stock and to the graft respectively. In fact, something of the kind has been observed in the case of the parasitic Balanophoræ (see vol. i. p. 194). Now supposing such an intermediate tissue were to be formed at the junction between a graft and its substratum, one or more shoots might spring from it and they would doubtless combine the characteristics of the two species employed as stock and scion.

In relation to the genesis of new forms of plants in nature, the question of the possibility of the existence of graft-hybrids is of secondary importance; but it is of no small moment in connection with the comprehension of the processes involved in hybridization; for, the researches suggested by this problem have led to the conclusion that the marks and attributes of a particular species which are perceptible to our senses are an outward sign corresponding to the ultimate structure and molecular composition of a specific protoplasm, and that wherever the special characters of two species are united in a single plant-form, that form is built up from protoplasm which owes its origin to a combination of the protoplasts of two parent-species.

It is only by adhering to this train of thought that one is able to understand how it is that, also in the matter of chronological development, the vital manifestation connected with the shape, anatomical structure, scent, and colour occupy in hybrids a position intermediate between the corresponding manifestations in the parental species. In the Botanic Garden at Vienna there has been for many years

a Buckthorn-shrub, named *Rhamnus hybrida*, which sprang from a cross between *Rhamnus alpina* and *Rhamnus Alaternus*. One of the parent-species, *R. alpina*, has deciduous foliage, *i.e.* leaves which are green in the summer and wither and drop in the autumn; the other, *R. Alaternus*, has evergreen leaves, which last through the winter and remain on the branches for two years. The hybrid, *R. hybrida*, possesses leaves which do not fall off in the autumn, nor yet last fresh and green for two years, but which maintain their verdure through one winter and fall in the spring when new shoots are sprouting from the buds. The behaviour of hybrids as regards their season of flowering is also very remarkable. From 1863 to 1874 I kept notes concerning the flowering of some fifty different kinds of Willow, growing in the Botanic Garden at Innsbruck, and each year made an entry of the day on which the first flower opened in each plant, whether a pure species or a hybrid.

EARLIEST DATE OF FLOWERING OF A NUMBER OF WILLOWS GROWING IN THE
BOTANIC GARDEN AT INNSBRUCK.

(The date given is the average for 12 years.)

Salix Cremsensis -	March 17	Salix Caprea - -	March 16	Salix daphnoides	March 18
" Mauternesia -	" 23	" Caprea - -	" 16	" purpurea -	April 7
" attenuata -	" 25	" Caprea - -	" 16	" grandifolia -	March 27
" Wimmeri -	" 26	" daphnoides	" 18	" incana - -	April 17
" Austriaca -	April 3	" grandifolia -	" 27	" purpurea -	" 7
" Seringeana -	" 3	" Caprea - -	" 16	" incana - -	" 17
" capnoides -	" 5	" cinerea - -	April 10	" incana - -	" 17
" intermedia -	" 6	" grandifolia -	March 27	" incana - -	" 17
" rubra - -	" 6	" viminalis -	April 3	" purpurea -	" 7
" Kernerii -	" 10	" viminalis -	" 3	" incana - -	" 17
" Oenipontana	" 12	" purpurea -	" 7	" incana - -	" 17
" auritoides -	" 14	" purpurea -	" 7	" aurita - -	" 19
" Fenzliana -	" 21	" retusa - -	" 21	" glabra - -	" 21
" retusoides -	" 21	" retusa - -	" 21	" Jacquiniiana	" 21
" alpigena - -	" 23	" retusa - -	" 21	" hastata - -	" 27
" excelsior -	" 23	" fragilis - -	" 13	" alba - -	" 27
" Ehrhartiana	" 29	" alba - -	" 27	" pentandra -	May 6

The name in the first column is that of a hybrid in each case, and the names on the same line in the second and third columns are those of its parent-stocks.

The above table, which gives the means of the dates recorded in 12 years of the first opening of the male flowers in 15 species and 17 hybrids produced from them by a variety of crosses, shows that the hybrids invariably flower on days between those on which the parent-species enter upon that stage of development. It will be observed that the two alpine Willows, *Salix retusa* and *Salix Jacquiniiana*, flowered on an average in the 12 years on the same day, and that their hybrid *Salix retusoides* kept also to that date.

We have hitherto dealt with those of the marks, attributes, and vital phenomena manifested by hybrids which are derived partly from the one parent-species and partly from the other, and we must now pass to the consideration of such characteristics as cannot be attributed to inheritance from those species. There is, in the first place, the fact that the majority of the hybrids produced from crosses develop

with striking rapidity and exuberance; they not uncommonly flower the very first year after they are sown, whereas the seedlings of the parent-species may not attain to the flowering stage for two or three years; and in respect of the size of the foliage, and still more that of the flowers, hybrids often exceed both parent-species. The latter circumstance is indeed one of the chief reasons why growers make such frequent use of the process of crossing. They are thus enabled to meet the demands of connoisseurs, who prefer to have plants with conspicuous flowers in their gardens. The augmentation in the size of the flowers usually ceases after the first, or at any rate after the second year. Subsequently, the flowers of hybrids become smaller again. On this account gardeners are in the habit of producing such hybrids as are especially valued for their large flowers over and over again by the original method. Of the large number of observations recorded on this subject we will here mention one as an example. *Isoloma Decaisneanum* of the order Gesneraceæ is the product of a cross between *Isoloma Tydæum* and *Isoloma sciadocalyx*. The seeds obtained after crossing germinate early, and the seedlings develop rapidly into exceptionally robust plants. The foliage-leaves are three times as large and the flowers twice as large as those of the parent-species; in addition, the flowers are much more numerous than on the parent-plants, and in consequence the hybrid has a much more imposing and showy appearance than either of its progenitors.

Many plants which grow on soil rich in humus in mountainous regions, such as the Lungworts (*Pulmonaria*) and Primulas (*Primula*), do not thrive particularly well in gardens, and certain species die after a short time even when cultivated with the greatest care. Yet the hybrids of such species flourish wonderfully well under similar circumstances. They blossom luxuriantly, and may be kept in a state of vigorous growth for many years. Examples of this are afforded by *Primula pubescens* and *Primula Venzoi*. One of the parent-stocks of *P. pubescens*, viz. *Primula hirsuta*, can only be reared if the soil used is expressly prepared for itself, and if several other special precautions are taken, whereas the hybrid, *P. pubescens*, grows exuberantly in ordinary garden-soil. The case of *P. Venzoi*, the hybrid-offspring of *Primula tyrolensis* and *Primula Wulfeniana*, is still more remarkable. Although both the parent species are reared with difficulty, even when the greatest care is bestowed upon their cultivation, *Primula Venzoi* will flourish with extreme luxuriance if planted close to them in the same soil and under the same external conditions.

Another phenomenon sometimes exhibited by hybrids is a change in the distribution of the sexes. It often happens, for instance, that hybrids produce pseudo-hermaphrodite female flowers and pseudo-hermaphrodite male flowers (cf. p. 294), even where both parent-species have true hermaphrodite flowers. In Willow hybrids a partial transformation of male into female flowers, and *vice versa*, has been not infrequently observed, and we then have monœcious catkins bearing flowers, half of which are female and half male. This change also occurs in true species, but only as a rare exception, whilst in the case of hybrids it is by no means uncommon.

Hybrids also exhibit the phenomenon known as the "doubling" of flowers, which depends upon the transformation of stamens into petals, independently of the action of tiny gall-mites, which are the frequent cause of doubling in other plants (*cf.* p. 548). Several hybrid Roses, Pinks, and Camellias are only known with double flowers.

It is difficult to explain the fact, repeatedly confirmed by observation, of the appearance in hybrids of characters which are not present in either parent-species, or rather which cannot be traced to inheritance from either of those species. Thus it sometimes happens that individual plants of a hybrid develop sinuate foliage-leaves with wavy outline, though in both of the parent-species the leaves are either entire or only slightly toothed. The hybrid *Salvia sylvestris* occasionally exhibits deeply sinuate radical leaves, whilst *Salvia nemorosa* and *Salvia pratensis*, the two species to which it owes its origin, never do so. Another instance of the same kind is that of a Stock, the hybrid of *Matthiola incana* and *Matthiola Maderensis*. Neither the one nor the other parent-species has sinuate leaves, yet here and there plants of the hybrid display foliage with the margins so deeply cut as to remind one at first sight of *Matthiola sinuata*. Again, in *Primula pubescens* the leaves are sometimes more deeply sinuate than in either *Primula Auricula* or *Primula hirsuta*. In hybrids of the Foxglove genus (*Digitalis*), flowers not infrequently make their appearance wherein the corolla is produced underneath into a spur as in the Toad-flax (*Linaria*). One hybrid produced by crossing two species of Water Lily, *Nymphæa Lotus* and *Nymphæa dentata*, displayed dark violet lines on its sepals which are not to be seen in either parent-species. Reference must also be made to the comparative frequency with which hybrids bearing white flowers spring from species with blue, violet, red, or yellow blossoms whose non-hybrid offspring only produce colourless flowers on very rare occasions. Lastly, we may mention the fact that as from species so also from hybrids varieties may be formed; but they have no permanence amongst the descendants of a race, passing into other varieties whenever it undergoes the restrictive influence of a change in external conditions.

3. THE ORIGIN OF SPECIES.

Genesis of New Species.—Derivation of Existing Species.—The Sub-divisions of the Vegetable Kingdom.

THE GENESIS OF NEW SPECIES.

It is now more than forty years since I discovered, on an island on the Danube not far from the little town of Dörenstein, a Willow which had till then remained unknown to Botanists. The plant in question was growing on the island in company with a number of other Willow-trees and Willow-shrubs belonging to the

species known as *Salix incana* and *Salix daphnoides* respectively, and it was apparently intermediate in form between those two species. The hairs, the system of ramification, the foliage, and the flowers resembled those of *S. incana* in some respects and those of *S. daphnoides* in others, and a single glance would have led any unbiassed observer to conjecture that he had to deal with the product of a cross between these two species.

This discovery,¹ made in one of the first years of my career as a student of Botany, chanced upon a time when Botanists were beginning to take a particularly keen interest in all cases of intermediate forms observed growing in a state of nature. Some of the leading men at that time refused to believe in the existence of any wild hybrids, and were of opinion that the supposed cases were *varieties* of species whose presence was to be explained by a tendency in the plant itself to change its form. They also held the view that all plants between which one or more intermediate forms had been found to exist were to be included in a single species, and, in accordance with this, they not infrequently treated three, four, or more kinds of plant previously classed as distinct species as being really "varieties" of a single species, because forms obviously intermediate between them, *i.e.* so-called "transitional forms", had been discovered. This practice was carried so far that several systematic Botanists of that day included in one species 5, 10, and even 15 distinct Hawk-weeds which had been previously described as separate species, the reason for the change being that they were all linked together by transitional forms. Another school of Botanists, on the other hand, recognized in most of the so-called transitional forms the results of natural crossing, but they did not deny the existence in plants of a capacity to form varieties in the Linnean sense in response to changes of soil or climate.

To my mind even at that time there could be no doubt which of the two opposing theories concerning the genesis, significance, and position of intermediate forms was to be preferred. The discovery of the hybrid Willow referred to led to my paying particular attention to plant-hybrids, and in the course of the last forty years I have made extensive series of experiments to clear up many obscure points, and to correct the prejudices which then prevailed.

One misconception as to the nature and significance of hybrids, which had great weight and found expression in the name of "bastard" assigned to them, consisted in the idea that they were contrary to nature. The German word "bastard" is defined by Grimm as a base and useless species. This prejudice was carried so far that Kant positively denied their independent existence, and believed they must necessarily die out with the first generation. Connected with this notion was another, according to which hybrids were destitute of the power of producing fertile seeds and propagating their kind sexually. It probably arose from observation of the hybrids of the Mullein genus (*Verbascum*), which in Central Europe are so common

¹The little paper recording the finding of this Willow, with some additional remarks, by Anton Kerner, was published in 1852 (Vienna, Zool. Bot. Ver. Verhandl. II., 1852). This seems to have been Kerner's second definite contribution to science; what would appear to be his first is printed in the same publication a few months previously.

and conspicuous that they were accepted as the results of crosses between two species even by those amongst the earlier Botanists who were most disinclined to recognize the existence of plant-hybrids. Now, these Mullein hybrids do not for the most part mature any seeds. The pistil itself is usually incompletely developed, and even if one or other of the fruit-capsules does develop, the ovules in it are abortive and infertile. Nevertheless it would be erroneous to say that no Mullein hybrid has ever produced seeds capable of germination. Two such hybrids were artificially generated in my garden, viz.:—*Verbascum rubiginosum*, by crossing *Verbascum Austriacum* with the pollen of *Verbascum phæniceum*, and *Verbascum pseudophæniceum*, by crossing *Verbascum Blattaria* with *V. phæniceum*. The former of these hybrids, it is true, never produced seeds capable of germination: but in the case of the second, although most of the capsules were empty and abortive, a few containing fertile seeds ripened; so that even the hybrids of Mulleins are not invariably sterile.

Anyone who will look beyond the limited range of that particular genus will be convinced that in respect of their capacity for sexual reproduction hybrids do not differ essentially from plants which have been admitted to be "true", permanent species by Botanists of all periods. For the case of a few of these true species, as, for instance, *Cochlearia Armoracia*, *Crambe tataria*, *Lilium bulbiferum*, *Lysimachia Nummularia*, *Rubus odoratus* and *R. Nutkaensis*, it has long been known that if the stigmas are dusted with pollen from the stamens in the same flowers very few seeds, if any, are set, whilst pollen from other flowers is obviously preferred by them. On the other hand, there are true species whose flowers are pseudo-hermaphrodite, i.e. they have the appearance of being bisexual, but are really unisexual (cf. p. 294). In one individual we find that the ovaries are fully developed, as also the stamens, but that no pollen capable of fertilizing ovules is produced in the anthers; in another plant the ovaries are imperfectly developed, whilst the anthers are filled with effective pollen. For seeds to be set in such circumstances two individuals at least are requisite, and pollen from a plant bearing pseudo-hermaphrodite male flowers must be transferred to the stigmas of the pseudo-hermaphrodite female flowers. Now *hybrids* with pseudo-hermaphrodite flowers also exist, and in their case, as in that of true species, two kinds of individual are requisite to produce seeds capable of germination. Supposing, however, in such a case that the two kinds of plant necessary for reproduction do not grow close together or do not flower simultaneously, or that one of them is altogether absent—a contingency which must often occur—fertilization cannot be effected, and consequently no seeds can be formed. It is scarcely necessary to amplify the proposition that dicecious hybrids behave in this respect in the same manner as true species, and that pollination and fruit-formation may in them be impeded likewise by dichogamy or by heterostylism. In many hybrids, again, as in true species, the relative positions of stamens and pistil, the height of the stigma, the length of the filaments, and other conditions of the kind are not conducive to autogamy, and consequently no transference of pollen from the anthers to the stigmas in the same flower can take place

either at the beginning or at the end of the period of bloom. Such hybrids are dependent upon foreign pollen, and if none is brought at the right time by wind or insects no pollination or fertilization takes place, and no seeds are developed.

Even these brief references to recently-discovered phenomena connected with fertilization are sufficient to indicate that the suppression of the function of fruit-formation in hybrids is due in most cases to the same causes as operate on true species. Innumerable experiments have proved that if at the proper time pollen of the right sort is placed upon the stigmas of hybrids fertile seeds are developed as in the case of true species.

We must now consider a statement which for long held its place in Botanical works owing to the positive manner in which it was enunciated by an eminent authority. The proposition in question, whilst admitting the fertility of hybrids, asserted that it was conditional on the stigmas being supplied with pollen from one or other of the parent-stocks, and that no fruit was formed as a result of autogamy. This assumption rested partly on certain series of experiments performed on garden-plants by the Botanist Koelreuter in the second half of the eighteenth century.¹ By crossing two species of Tobacco-plant (*Nicotiana rustica* and *Nicotiana paniculata*) Koelreuter produced a hybrid which in its characteristics was an exact mean between the two parent-species. The stigmas in the flowers of this hybrid were then dusted with pollen from one of the parents, and the result of this second cross was another hybrid, the characters of which resembled those of the species which supplied the pollen more closely than was the case with the first hybrid. The same treatment was applied to the second hybrid, and thus, after three generations, a plant was evolved completely resembling the male progenitor. The first hybrid had, therefore, in a sense, "reverted" to that particular parent-species. The "reversion" of the hybrid to the other parent-species was similarly procured after three generations. Such a result could naturally not have ensued if the action of the pollen of the parental stocks on the hybrid had not been entirely effectual. It is accordingly quite true that hybrids are fertile when the pollen used to fertilize them is taken from either of the parent-species, but the further assertion that they are sterile if their own pollen is employed for the purpose is incorrect, at any rate as a universal proposition. Koelreuter's own conscientious experiments show conclusively that it is possible for hybrids to bring fruits to maturity as a result of autogamy, and that, as a matter of fact, the majority do develop such fruits. We may also refer to the large number of plants with ornamental flowers, such as Begonias, Pansies, and Pinks, which every year in our gardens produce seeds autogamously, and are reproduced in great numbers by means of those seeds (see p. 556). Some interesting experiments have also been made on *Medicago media*, the hybrid of *Medicago falcata* and *M. sativa*. This plant, which is, in many places, cultivated on a large scale for fodder, is propagated continuously by seeds which are in a very

¹ Joseph Gottlieb Koelreuter (1733-1806) was the first to investigate the question of hybridisation scientifically and thoroughly. His work, which ranks with the best of modern times, is contained in his *Vorläufige Nachricht von einigen das Geschlecht der Pflanzen betreffenden Versuchen und Beobachtungen* (published 1761-1766); a convenient reprint was issued in 1893.

subordinate degree, if at all, dependent on the parent-species for their production. Nay more, it would be prejudicial were one of those species to supply the pollen seeing that the fertility of this hybrid is diminished thereby. We have here a case of a hybrid manifesting enhanced fertility as compared with one of its parents; for *Medicago falcata* is one of those Papilionaceæ in which autogamy is attended with very small result. It has been ascertained that in cases where the flowers of that species are thrown upon their own resources for pollen, out of every 30 flowers only two or three fruits containing seeds capable of germination are matured. If flowers of *Medicago falcata* are crossed with pollen belonging to another species, such as *Medicago sativa*, a much larger number of fruits is produced, and it is stated that the number of seeds is almost doubled. *Medicago media* usually sets from six to eight pods in each raceme if the flowers depend upon their own pollen for fertilization. If, however, pollen is brought to them from *Medicago falcata* the degree of fertility is strikingly reduced; the flowers so crossed either remain quite empty or develop pods whose seeds are not capable of germination. *Medicago media* is therefore an instance of a hybrid which is actually injured by being crossed with one of the parent-species, but is successfully reproduced by autogamy. The upshot of all these experiments is that the results of autogamy are no different in hybrids from what they are in species.

We may infer from the same experiments in what way reversions of hybrids to their parent-species should be regarded. Botanists possessed with the idea that every hybrid was the product of some process contravening the laws of nature imagined that this anomaly must be counteracted, and that this was effected by a tendency existing in the hybrid's descendants to approximate sometimes to one and sometimes to the other parent-species, so that in the course of a few generations they would completely revert to the form of a true species. As the accounts given by gardeners seemed to confirm the fact of the occurrence of such reversions, no doubt was raised as to the soundness of this view. The reports of gardeners on the subject were, however, founded on inaccurate observation, want of knowledge, and self-deception. In former years the phenomena of pollen-transport in the case of pseudo-hermaphrodite, dichogamous, and heterostyled flowers, and many other things connected therewith, were not appreciated at their full value; to most gardeners they were altogether unknown, and it was only in the rarest instances that any measures were taken to preserve the species and hybrids reared in gardens from extraneous pollen. The majority of growers had no suspicion that the fruit formed on a particular cultivated hybrid might be due to the effect of pollen conveyed by the wind or by insects from one of the parent-species flourishing in the vicinity, and if they noticed that the seedlings arising from that fruit exhibited characteristics approximating to either of the parent-species they were in the habit of calling the phenomenon a reversion. But if a gardener takes care that the flowers of a hybrid under cultivation are only supplied with pollen developed in flowers of their own kind whilst that of other species is excluded, the plants which arise from the seeds of the hybrid exhibit the characters of that hybrid unaltered. Thus,

hybrids prove true to seed, to use a gardener's expression, and there is no truth in the assertion that they have an innate tendency to revert to one of the parent-forms.

At one time the attempt was made to distinguish two sorts of hybrids—those arising between *species*, which were regarded as sterile, and those arising between *races*, which were regarded as fertile. By "*races*" are understood forms which, whilst not differentiated by characters of sufficient importance to rank as species, are yet reproduced by seed and transmit their characters to their offspring. They seem to stand midway between what are called varieties and sub-species. Forms arising by the crossing of species were termed hybrids, those arising by the crossing of races "*blendings*". But in this matter Botanists argued in a hopeless circle. Firstly, it was said that if races were crossed the intermediate forms were fertile; whilst those springing from species were sterile; and, secondly, the distinction between races and species was defined as consisting in the fact of the fertility of the intermediate forms produced by crossing races, as compared with the infertility of those derived from crosses between species. A distinction founded on such reasoning as this is, of course, destitute of any value or meaning. What, then, is the difference between races and species? There are certain forms which have a similar physiognomy, an agreement in certain striking particulars. They are bound together by these common characteristics into a single group, and it must be supposed that they are nearly allied in respect of their origin also. But no more than *affinity* can be predicated by characters which, though perhaps less striking than the others, are yet transmitted unmodified to descendants and prove themselves to be constant attributes. It has been sought to apply the term "*races*" to nearly akin forms of the kind. But the degree of variation has nothing to do with the conception of a species; the essential point is that the characters wherein the variation is manifested are transmitted unchanged to the descendants, and this happens as a fact in all the cases to which the name of race has been affixed. The use of the term would obviously imply quite a different connotation of the name of species from that which Linnæus, with logical exactitude, attached to it. According to him a species was not an assemblage of individuals of the same form, but an assemblage of individuals of different forms, constituting a group of units and not itself the unit of the system. If, like the French system, we were to distinguish the groups of nearly allied species as "*petites espèces*" from those exhibiting more marked differences and less nearly akin to one another, which would be known as "*grandes espèces*", that would involve quite sufficient recognition of the difference which exists in various degrees between members of the two categories in question; but the introduction of the word "*race*" side by side with the word "*species*" suggests the idea of some line of demarcation between the two such as does not in reality exist. Again, if there is no definite boundary between race and species the separation of blendings from hybrids also fails, and with it the proposition that only those hybrids are fertile which are the offspring of races.

In respect of fertility, then, there is no difference between hybrids and species.

In the one as in the other we find those floral contrivances for bringing about cross-fertilization in the first place and autogamy in the second, of which an account was given in the first part of this volume; in the one case as in the other cross-fertilization often takes place as a result of those contrivances, and both categories include forms which are incapable of self-fertilization, and only develop fruits and fertile seeds in consequence of geitonogamy or xenogamy. Seeing that it has been ascertained also that, provided the pollen from other species is excluded, hybrids transmit their form unchanged to their posterity, and that the substitution of brood-bodies for fruits as a means of reproduction and the enhancement of the development of those bodies in the event of there being no fruit, are phenomena common to species also, we come to the conclusion that no line of demarcation between hybrids and species exists in respect of the function of propagation.

The consideration of all these facts led me years ago to raise the question whether hybrids could originate species,¹ and to answer it in the affirmative. Looked at from this point of view, the hybrids which have been and are being produced in nature acquire a special significance, and it becomes important to form a correct notion as to their existence, behaviour, and distribution in localities where the life of plants is untrammelled and undisturbed. Only the vegetation of Europe has been thoroughly studied in this connection, yet this alone affords a fund of information, and we may take it for granted that what is true for Europe will apply likewise to the other quarters of the globe.

We shall be rather below than above the mark if we estimate at a thousand the number of wild hybrids belonging to the Flora of Europe which have been brought to light during the last forty years. Of these only a small proportion are of the class of Cryptogams, but this circumstance is due to the fact that it is only lately that Botanists have paid any attention to hybrid Cryptogams. Future researches will no doubt establish the hybrid nature of many so-called "transitional forms". Amongst Mosses in particular, several hybrids arising from species which grow in ditches and marshy places (*Hypnum aduncum*, *H. fluitans*, *H. lycopodioides*, &c.) have been discovered. A few hybrids of the genera *Orthotrichum*, *Grimmia*, *Physcomitrium*, and *Funaria* have also been identified. Fern hybrids are known in the genera *Aspidium*, *Asplenium*, *Ceterach*, *Polypodium*, and *Scolopendrium*. *Scolopendrium hybridum*, which was observed in Istria, is especially remarkable as being the result of a cross between two species possessing widely different forms and included in different genera. The parent-species of this hybrid are, firstly, *Scolopendrium officinarum*, which is glabrous and grows in clefts in damp, shady rocks and walls; and, secondly, *Ceterach officinarum*, which has the under surfaces of its fronds thickly covered with brown scales and flourishes in the crevices of dry walls exposed to the sun. Amongst the Horse-tails we may mention *Equisetum inundatum*, a rather common hybrid, which owes its existence to the crossing of *Equisetum arvense* and *E. limosum*.

In the division of the Coniferæ no less than seven hybrids have been recently

¹ Oesterreich. botanische Zeitschrift xxi. p. 34 (1871).

identified, and this fact is of no little significance when taken in connection with the circumstance that Europe only possesses 41 species of Conifers. *Juniperus Kanitzii*, the hybrid offspring of *Juniperus communis* and *J. sabinoides*, is a very instructive instance owing to the great diversity in the form of the two parent-species.

Comparatively few hybrids occur amongst Grasses. The majority belong to the genus *Calamagrostis*. Strangely enough, most hybrid grasses have arisen from crosses between species of different genera, as, for instance, *Festuca* and *Lolium*, *Triticum* and *Elymus*, *Triticum* and *Ægilops*. The hybrid derived from *Ægilops ovata* and *Triticum sativum*, and known by the name of *Ægilops triticoides*, and the hybrid *Ægilops speltæformis*, obtained by crossing *Ægilops triticoides* with *Triticum sativum*, have been the subject of lively discussion in their time, and have contributed not a little to clearing up our ideas concerning hybrids. As a set-off to the Grasses, the groups comprising Reeds, Rushes, and Sedges include a comparatively large number of hybrids. For example, in the genus *Carex* instances have been discovered in the most widely different localities.

Amongst Lilifloræ and Iridæ only a few wild hybrids have been found, but on the other hand a large number occur amongst Orchidaceæ all over Europe. It is striking how many of these Orchid hybrids spring from species which are placed by Botanists in different genera. Hybrids are known, for instance, which are derived respectively from *Aceras* and *Orchis*, from *Anacamptis* and *Orchis*, from *Cœloglossum* and *Orchis*, from *Gymnadenia* and *Orchis*, from *Himantoglossum* and *Orchis*, from *Serapias* and *Orchis*, from *Gymnadenia* and *Nigritella*, and from *Epipactis* and *Cephalanthera*. The hybrid *Epipactis speciosa*, lately discovered in the Erlafthal of Lower Austria, is the result of a cross between *Epipactis rubiginosa* and *Cephalanthera alba*, and is of special interest on account of its manifesting characters strongly resembling those of species indigenous to regions at a great distance from the place where the hybrid occurs, for at first sight *Epipactis speciosa* might easily be taken for *Epipactis gigantea*, which is a native of North America, or for the Japanese species named *Epipactis Thunbergii*.

Hybrids are comparatively numerous amongst the Pond-weed group (*Potamogeton*). These are aquatic plants which discharge their pollen in the form of clouds of dust, and at the season of pollination raise their flowers above the surface of the water. Owing to their being completely protogynous (see p. 310), autogamy is out of the question. The crossing of pairs of species is especially promoted by the circumstance that the different species flower in definite succession, so that always just at the time that one species is terminating its period of bloom another is coming into flower.

Plants which have their flowers in catkins (*amentaceous*), such as Oaks, Birches, Alders, Poplars, and Willows, produce an uncommonly large number of hybrids. In Willows pollination is effected by insects, in the other genera by the wind. This gives occasion for us to raise, in connection with this group, the question whether hybrids originate more frequently from entomophilous or from anemophilous plants.

The fact that many more than a hundred Willow hybrids are known looks as if the agency of insects were the more favourable to hybridization. At the same time we must bear in mind that the number of species of Willow in Northern and Central Europe is very large, whilst the number of different Birches, Alders, and Oaks is small. Taken in relation to the number of species, the hybrids belonging to the plants last mentioned are no less numerous than those of Willows, and it appears, therefore, that hybrids occur as frequently amongst plants whose pollen is dispersed in the form of dust as amongst plants with adhesive pollen which is transported by insects. The prevalence of hybrids amongst Pond-weeds points to the same conclusion. A comparison between the Docks and Polygonums even indicates that in anemophilous plants, such as the Docks, hybrids come into existence more readily than in the case of entomophilous plants as represented by the Polygonums, for in scarcely any genus is the number of hybrids so great in proportion to the number of species as in the Dock genus, and the ratio is certainly higher than it is with the Polygonums.

As regards the Caryophyllaceæ it is remarkable that *Dianthus* has many hybrids and *Silene* few, although these two genera resemble one another in the distribution of their sexes and in being chiefly visited by lepidopterous insects. In the genus *Viola* hybrids are extremely common. It has been shown that many *Violas* which were formerly designated as "transitional forms" are in reality hybrids, and thus the grounds upon which systematic Botanists treated whole series of species as one only are removed. As with the *Violas* in Central Europe so also with their allies the *Cistuses* in the South, hybrids are numerous; several kinds of *Cistus* hybrids occur so commonly that they were described as species by the Botanists of former times.

It is noticeable in the Cruciferae that no hybrids are formed in nature between the numerous annual species of this family. There are also only a few hybrids known which are derived from the perennial species. The genera *Roripa* and *Draba* are, however, exceptional in this respect. The case of Ranunculaceæ is similar. In the comprehensive genera *Aconitum*, *Helleborus*, and *Ranunculus*, only a few hybrids have been identified with certainty, whilst in *Anemone* and *Pulsatilla* there are almost as many hybrids as species. The case of the hybrid Water-lily *Nuphar intermedium* will be discussed later on.

Many hybrids are known in the genera *Tilia*, *Hypericum*, *Malva*, *Rhamnus*, *Pistacia*, *Acer*, *Euphorbia*, and *Epilobium*, the last alone including fifty different kinds. This makes it all the more remarkable that so varied a family as the Umbelliferae yields very few hybrids. Of the numerous hybrids belonging to the Saxifragaceæ we may mention as specially noteworthy those derived from species which differ exceedingly from one another in form and size. One cannot easily imagine two plants in the limits of a single genus which present a greater contrast to one another in respect of flowers, leaves, and general mode of growth than is exhibited in the following cases:—*Saxifraga cæsia* and *S. mutata*, *S. aizoon* and *S. cuneifolia*, *S. aizoides* and *S. squarrosa*, and yet hybrids have sprung from the crossing of these species.

About two hundred hybrids, for the most part fertile, have come into existence in nature within the family of the Rosaceæ. The genera *Geum*, *Potentilla*, *Rubus*, *Rosa*, and *Sorbus* are inexhaustible in the formation of hybrids. On the other hand, the Papilionaceæ, a family allied to the Rosaceæ, is peculiarly wanting in hybrids.

This discrepancy between nearly-related families in respect of the number of their hybrids is again noticeable in the class of plants known as the Monopetalæ. The Labiatæ, e.g. the genera *Ajuga*, *Prunella*, *Calamintha*, *Lamium*, *Marrubium*, *Mentha*, *Salvia*, and *Stachys* include numbers of hybrids, whilst the Boraginaceæ have very few. Of the latter only one or two hybrids are known, and these belong to the genera *Pulmonaria* and *Symphytum*. The Scrophulariaceæ and Rhinanthaceæ have long been noted for the great variety of their hybrids; the genera *Pedicularis* and *Verbascum* in particular exhibit a great wealth of forms, *Pedicularis* in alpine regions and *Verbascum* on the shores of the Mediterranean. *Verbascum* alone includes more than fifty. In the case of Gentianaceæ, also, the products of a great number of different crosses are found in the Alps, the chief parent-species being the long-stalked *Gentiana lutea*, *G. Pannonica*, *G. punctata*, and *G. purpurea*. Primulaceæ, whether growing on the upper or the lower levels of mountains, are famous for the abundance of their hybrids. In the genera *Androsace*, *Primula*, and *Soldanella* the number of hybrids identified by Botanists surpasses the number of the species from which they have sprung. The Ericaceæ, although comparatively poorly represented in Europe, exhibit several hybrids derived from the genera *Erica*, *Rhododendron*, and *Vaccinium*.

Hybrids are also specially numerous in the family of the Rubiaceæ, the genus *Galium* being the most prolific in this respect. But the greatest number of all is to be found amongst the Compositæ. More than two hundred hybrids have been identified in the genera *Achillea*, *Carduus*, *Centaurea*, *Cirsium*, *Hieracium*, *Inula*, and *Lappa* alone. Of hybrid Compositæ the following are particularly worthy of notice:—*Erigeron Hülsenii*, which is the result of a cross between *Erigeron Canadense*, an annual species brought into Europe from America, and *Erigeron acer*, a perennial species indigenous to Europe, and, secondly, the Cudweed hybrids, *Filago mixta*, *F. neglecta*, *F. subspicata*, &c., which spring from crosses between annual species, and are, therefore, exceptional, for annual species in general rarely produce hybrids.

In many cases only a few individual instances of these natural hybrids have been observed; in some, indeed, one single specimen alone has as yet been discovered. The majority, however, grow by the hundred or by the thousand in the localities proper to them, and many are represented by immense numbers of plants, and possess a wide area of distribution. *Salvia betonicifolia*, a hybrid derived from *Salvia nemorosa* and *S. nutans*, occurs as commonly as its progenitors in places on the grassland in the central parts of Siebenbürgen (Hungary); *Marrubium remotum*, a hybrid of *Marrubium peregrinum* and *M. vulgare*, is to be found everywhere on the plains of South-Eastern Europe, especially in the flat country by the Theiss and

the lower Danube; *Roripa anceps*, the hybrid of *Roripa amphibia* and *R. sylvestris*, is met with all over the district forming the basin of the Baltic; *Primula digenea*, a hybrid derived from *Primula vulgaris* and *P. elatior*, grows in its thousands in the upland meadows of the Eastern Alps; *Betula alpestris*, produced by the crossing of *Betula alba* and *B. nana*, is met with in great abundance in the Jura, in Scandinavia, and in the North of Russia, and here and there entire copses are composed of it; *Nigritella suaveolens*, a hybrid produced from *Gymnadenia conopsea* and *Nigritella nigra*, is so common in the Central Alps, for instance, in the Pusterthal of Tyrol, that hundreds of specimens are sometimes encountered in a single meadow; *Primula Salisburgensis*, the hybrid of *Primula glutinosa* and *P. minima*, is represented by a host of plants on the Tyrolese Alps, as, for instance, on the Muttenjoch and the neighbouring mountains which separate the Gschnitzthal from the Obernbergthal.

Several hundreds of other cases of the kind might be mentioned, but the limits of this book will not allow me to do more than give the following names selected from the long list that lies before me:

HYBRID.	PARENTS.
<i>Asplenium Germanicum</i>	<i>Asplenium Ruta-muraria</i> × <i>A. septentrionale</i> .
<i>Calamagrostis acutiflora</i>	<i>C. arundinacea</i> × <i>C. epigeios</i> .
<i>Carex Bœnninghausiana</i>	<i>C. paniculata</i> × <i>C. remota</i> .
<i>Scirpus Duvallii</i>	<i>S. lacustris</i> × <i>S. Pollichii</i> .
<i>Juncus diffusus</i>	<i>J. effusus</i> × <i>J. glaucus</i> .
<i>Orchis Dietrichiana</i>	<i>O. tridentata</i> × <i>O. ustulata</i> .
<i>Potamogeton spathulatus</i>	<i>P. polygonifolius</i> × <i>P. rufescens</i> .
<i>Populus canescens</i>	<i>P. alba</i> × <i>P. tremula</i> .
<i>Salix Austriaca</i>	<i>S. grandifolia</i> × <i>S. purpurea</i> .
<i>Rumex maximus</i>	<i>R. aquaticus</i> × <i>R. Hydrolapathum</i> .
<i>Polygonum mile</i>	<i>P. Hydropiper</i> × <i>P. Persicaria</i> .
<i>Cistus Florentinus</i>	<i>C. monspeliensis</i> × <i>C. salvifolius</i> .
<i>Draba Hoppeana</i>	<i>D. Fladnizensis</i> × <i>D. Carinthiaca</i> .
<i>Roripa stenocarpa</i>	<i>R. palustris</i> × <i>R. sylvestris</i> .
<i>Pulsatilla Hakelii</i>	<i>P. patens</i> × <i>P. pratensis</i> .
<i>Drosera obovata</i>	<i>D. longifolia</i> × <i>D. rotundifolia</i> .
<i>Epilobium salicifolium</i>	<i>E. alsinifolium</i> × <i>E. montanum</i> .
<i>Sorbus latifolia</i>	<i>S. Aria</i> × <i>S. torminalis</i> .
<i>Potentilla procumbens</i>	<i>P. erecta</i> × <i>P. reptans</i> .
<i>Mentha nemorosa</i>	<i>M. aquatica</i> × <i>M. sylvestris</i> .
<i>Pedicularis atrorubens</i>	<i>P. incarnata</i> × <i>P. recutita</i> .
<i>Verbascum rubiginosum</i>	<i>V. Austriacum</i> × <i>V. phæniceum</i> .
<i>Acanthus spinulosus</i>	<i>A. mollis</i> × <i>A. spinosissimus</i> .
<i>Gentiana Charpentieri</i>	<i>G. lutea</i> × <i>G. punctata</i> .
<i>Primula pubescens</i>	<i>P. Auricula</i> × <i>P. hirsuta</i> .
<i>Vaccinium intermedium</i>	<i>V. Myrtillus</i> × <i>V. Vitis-idaea</i> .
<i>Erica Mackayi</i>	<i>E. ciliaris</i> × <i>E. Tetralix</i> .
<i>Cirsium tataricum</i>	<i>C. canum</i> × <i>C. oleraceum</i> .
<i>Lappa pubens</i>	<i>L. minor</i> × <i>L. tomentosa</i> .
<i>Hieracium stoloniflorum</i>	<i>H. aurantiacum</i> × <i>H. pilosellæforme</i> .

The fact that hybrids exhibit every conceivable degree of frequency of occurrence might lead one to suppose that the rare hybrids were those that had been most recently produced, and that they exist only as isolated plants because they have not

yet had time to disperse and multiply. This conception would not, however, accord with the actual condition of affairs. In point of fact, the floral contrivances which exist for promoting crosses between different species occasion a constant origination of hybrids, but it is certainly not the case that they all have the prospect of becoming new species. Many are called, but few are chosen. In only a fraction of the total number of fresh plant-forms produced yearly by inter-specific crosses do we find the power to survive and multiply. The first condition that must be fulfilled if a hybrid is to become a species is that it be fertile, i.e. that its flowers yield seeds capable of germination as a consequence of fertilization with their own pollen. By "their own pollen" is here meant not only that which is developed in the same flower as the stigma which receives it, or in some flower on the same plant, but also pollen belonging to other plants provided they belong to the same hybrid-formation. To this condition another is added in the case of dioecious, pseudo-hermaphrodite, and completely dichogamous flowers, viz.: that several individuals of the hybrid must make their appearance at the same time, and that of these at least one must bear male flowers and one female flowers. If we suppose the case of a Willow hybrid, of which all the individual-plants bear catkins of male flowers only, obviously no propagation by means of fruits is possible. If none but female flowers are borne, these may be crossed with the parent-species and give rise to goneoclinic hybrids (cf. p. 559), and perhaps, in addition, ternary hybrids may be produced, but no unmodified descendants can be expected from the fruits of a Willow of the kind. The same thing applies in the case of *Cirsium*, the separate individuals of this genus being differentiated into those bearing pseudo-hermaphrodite male flowers and those bearing pseudo-hermaphrodite female flowers (see p. 294). This affords sufficient explanation of the fact that although Willows and *Cirsiums* are continually developing numberless hybrids, few instances are known which one can affirm to be the beginnings of new species. It usually happens, in fact, in the case of these hybrids, that all the plants which arise together at a particular spot are furnished exclusively either with true or pseudo-hermaphrodite male flowers, or else with true or pseudo-hermaphrodite female flowers. The goneoclinic hybrids produced from the latter are for the most part represented by greater numbers of individuals. Moreover, amongst those individuals both sexes much more frequently make their appearance; hence, they have a far better prospect of being preserved.

The development of a hybrid into a species is also dependent on the conditions determined by the habitat. When a species thrives well at a particular place, is represented by a large number of individual plants, and renews itself in descendants which are in the main unchanged, it may be assumed that the organization of that species is suited to the soil and climate of the habitat in question. If there were no such harmonious relation there could be no question of the species flourishing, but on the contrary it would sooner or later die out. This suitability of the climate and soil to the organization manifested in the plant's external form must also exist in the case of the newly developed hybrid if the few individuals which spring up at any particular place are to survive in their original settlements, and to give rise to

a numerous progeny. Sometimes such suitability does exist, but sometimes also it does not. In the latter case the hybrid is suppressed as soon as it sees the light. But even if its organization is adapted to the soil and climate of the place of origin, it has to enter upon a struggle with the species already established there, and especially with its own parent-species. If the latter grow luxuriantly and in large numbers at the spot, it is not easy for the new form to take possession of the ground. In two cases only is there any prospect of the place of origin becoming a permanent home for the hybrid's descendants: firstly, where the hybrid, in virtue of its particular attributes, is equally well, or perhaps even better adapted to the habitat of the parent-species than are the plants already established there, and secondly, when the hybrid originates at a spot more or less removed from the place where the parent-species grow and encounters conditions of soil and climate which agree with it better than with the parent-species.

That these conditions of the origin of species from hybrids are sometimes fulfilled will now be shown by a few examples. In the Tyrolean Alps, to the south of Innsbruck, at the head of the valleys known as the Stubai Thal and the Gschnitzthal, there are certain mountains which rise steeply to a height of from 2500 to 3000 metres. The base of these mountains is composed of crystalline schist; midway up their ascent mixed strata of schist and limestone are encountered; and above these strata there is limestone and also dolomite, rising abruptly and forming the peaks and ridges. Half-way up the sides, where the soil exhibits great variety, an extraordinarily rich flora is developed. Plants which are, except in this instance, peculiar to schist formations, and others usually only found on limestone, here grow close together. Amongst other species the Alpine Roses, *Rhododendron ferrugineum* and *R. hirsutum*, grow side by side on the same soil and on the same slopes. Associated with them is a third species of Alpine Rose, *Rhododendron intermedium*, which has sprung from the crossing of *R. ferrugineum* and *R. hirsutum*. At several places, e.g. on the eastern and northern slopes of the Hohe Burgstall, in the Stubai Thal, and on the Padaster Alp in the Gschnitzthal, *Rhododendron intermedium* occurs more commonly than either of the parent-species. Like the latter, it grows on soil rich in humus, flowers abundantly, develops fruits with fertile seeds, and transmits its characteristics unaltered to its descendants. Here and there isolated plants are found which must be ranked as goneoclinic hybrids, but plants of *Rhododendron intermedium* form the larger proportion of the Alpine Roses which clothe the mountain-sides. This form accords in every particular with the requirements demanded of a species, and is quite as much a systematic entity as either *R. ferrugineum* or *R. hirsutum*. The following is the explanation of how this has come to pass: The colour of the flowers is a little lighter than in *R. ferrugineum* and richer than in *R. hirsutum*; it is a brilliant carmine tint, and enables one even at a distance to identify every plant of the hybrid. Hive- and bumble-bees hovering about in search of honey are more attracted by flowers of *R. intermedium* than by the others, owing to the superior brilliancy of their coloration, and the result is that these flowers are

crossed with pollen of their own kind. If no insects appear upon the scene, autogamy takes place. In either case fertile seeds are developed, and give rise to plants which do not differ from the parent-form. In places where detritus from the adjacent limestone and dolomitic cliffs is mixed with the humus of the soil the seedlings thrive distinctly better than those of *R. ferrugineum* and no less well than those of *R. hirsutum*. Thus, so far as the soil is concerned, *R. intermedium* has an advantage over *R. ferrugineum*, and in respect of insect-visits it is better off than either of the parent-species. These advantages, though apparently insignificant, are not merely sufficient to prevent *R. intermedium* from yielding to the parent-species in the struggle for existence at the places in question, but even give it rather a better chance of prevailing.

As a second instance, we will take *Salvia sylvestris*, the hybrid offspring of *Salvia nemorosa* and *Salvia pratensis*. This plant grows in dry meadows all over the low country to the south of Vienna, as, for instance, on the banks of the river Leitha, which separates Austria proper from Hungary. The landscape there is slightly undulating, the elevations are composed of boulders and clay, and wherever the latter is present in great quantities, especially on the gentle slopes of the rising ground, *Salvia nemorosa* constitutes an important item in the vegetation. The hollows are full of a dark moist earth, with a rich admixture of humus, and there we find meadows in which *Salvia pratensis* grows luxuriantly. These two kinds of habitat usually pass quite gradually into one another, and the parts common to both consist of dry meadow-lands. *Salvia nemorosa* does not thrive in the intricate grass-carpet of these meadows, and is rarely to be seen there, whilst for *Salvia pratensis* the soil is too dry, so that that species also is but poorly represented on the areas in question. On the other hand, these dry meadows are the most suitable ground for the hybrid *Salvia sylvestris*, and it thrives exceedingly upon them. Its flowers are much visited by insects; its fruits ripen in as large numbers as in the case of *S. nemorosa* or *S. pratensis*, and have been found by experiment to be fertile in a proportion of more than 60 per cent. *Salvia sylvestris* has therefore scattered itself all over this dry meadow-land, and manifests all the characteristics essential to our conception of a species.

A third example is *Nuphar intermedium*, a hybrid derived from *Nuphar luteum* and *Nuphar pumilum*. This plant grows in lakes in the Black Forest and in the Vosges. It is also scattered over North Germany, and occurs with increasing frequency in Central and Northern Russia and in Sweden. It has been found as far north as Lapland. At the northern extremity of this large area of distribution *Nuphar intermedium* is more abundant than the species from which it is derived; indeed in many places it occurs in their absence, and in fact passes beyond the northern limits of their area of distribution. In these situations there is, of course, no possibility of the hybrid's crossing with either of the parent-species or of the formation of goneoclinic hybrids. *Nuphar intermedium* subsists independently there, multiplies without change of form, and has in fact established itself as a species. This phenomenon is explained as follows: The northern limit of

the distribution of each of the three Water-lilies in question is determined by their not being able to ripen fruits beyond that limit. Of the three, *Nuphar luteum* flowers the latest, and therefore its fruits are also the latest to ripen, whence it follows that it is the first to fall behind; that is to say, it reaches the northern limit of distribution sooner than the others, and ceases to ripen fruit in regions where the others are still able to do so. But *Nuphar pumilum* and *N. intermedium* are also different from one another in this respect. In Norbotten and Lapland *Nuphar intermedium* ripens its fruits a little earlier than *N. pumilum*, and it is consequently able to extend rather further north than *N. pumilum*. The further north plants go, the shorter becomes the time allotted for the performance of their annual work; and those which ripen their fruits early have a great advantage over those which ripen later. Concerning *Nuphar intermedium*, it has also been ascertained that the individual plants produced in nature are more fruitful than those reared in gardens from artificial crosses. In the case of plants obtained in this manner in the Botanic Gardens at Königsberg each capsule contained from 15 to 18 fertile seeds, whilst capsules ripened in the small lakes of the Black Forest contained from 38 to 63, and others taken from plants growing in Lapland contained from 41 to 72 such seeds. From these data we may infer, in the first place, that *N. intermedium* is most prolific in situations beyond the range of the parent-species; and, secondly, that it would be wrong to suppose that because a hybrid may be comparatively infertile or actually sterile in a particular locality, such infertility is a characteristic of the plant wherever it may occur.

As may be gathered from the above account of these three examples, the advantage which a hybrid may possess over the parent-species, whereby it is enabled to subsist and multiply side by side with those species, is not always of the same kind. In one case it is the more vivid coloration of the flowers, in another the fact of the hybrid being better adapted to a particular state of the ground, whilst in the third the earlier ripening of the fruits, which enables the hybrid to stand a more rigorous climate, gives the requisite advantage. These do not, of course, exhaust, by a long way, the possible sources of superiority, and there are many instances of hybrids which thrive better than the parent-species when the climate becomes milder, moister, or drier, as the case may be. It is obvious that of all the different advantages which may come into play those connected with climatic conditions are the most important, and the genesis of hybrids is probably most frequently due to the operation of this kind of advantage.

Far too little significance has been attached to the fact that the greater number of hybrids are not found in districts where the parent-species grow together with equal luxuriance, but occur where one or other of those species is meagrely represented, owing to the climate not being favourable to its distribution. Again, large numbers of hybrids are found in parts where the boundaries of several species coincide. In Europe such regions exist in the strips of land where the advance-posts of the Floras of the Baltic and Black Sea, and the Floras of the Baltic and the Mediterranean, respectively, encounter one another, and particularly in the

lower limits of the Alpine Flora. Another characteristic of these borderlands is the fact that the separate hybrids growing on them are almost always represented by a large number of individuals, and the consequence is that there is no great chance of their crossing with the parent-species and gradually reverting, in successive generations, to those species. If isolated individuals belonging to a particular hybrid grow in the midst of thousands of plants of the parent-stocks, their stigmas will, in all probability, be dusted with pollen from the latter species. This probability diminishes, however, as the number of individuals of the parent-species flowering in the same locality as the hybrid diminishes; if that number is small the hybrid is thrown mainly upon its own resources for fertilization, and, provided it is self-fertile, there is nothing to prevent its multiplying and becoming dispersed.

Connected with the above is the further fact that in the neighbourhood of a hybrid which has become a species there is sometimes no trace of one of the parent-species, it having completely died out. The slightest change in climatic conditions may cause the plants of a particular stock to succumb at the confines of the stock's area of distribution, where they are only present in small numbers, and are anything but strong; and when this happens we find the other parent-species alone growing side by side with the hybrid, and even that species is possibly not so well adapted as the hybrid to the altered conditions. Of cases in point we will select two from the East of Europe and two from the West.

When *Epilobium alsefolium* and *Epilobium palustre* are crossed a hybrid is obtained which, when fertilized with its own pollen, yields a large quantity of fertile seeds. The plants reared from these seeds exhibit the same characteristics as the plant from which the seeds were taken. This hybrid grows together with the parent-species in the Riesengebirge, and has received the name of *Epilobium scaturiginum*. It is likewise a native of the Bihar Gebirge, on the confines of Hungary and Transylvania, and is of very common occurrence in the springs and rivulets in the vicinity of the Hochkamm (a mountain of this chain). Yet, of the two parent-species, only one, viz. *Epilobium palustre*, grows amongst these mountains. Again, *Prunella hybrida* is a hybrid springing from *Prunella laciniata* and *Prunella vulgaris*. It is widely distributed in the Wienerwald district, and in some places is commoner than the parent-species, whilst in Moravia and Bohemia it occurs in places where one of the latter, viz. *Prunella laciniata*, is entirely absent. A third instance is afforded by *Primula brevistyla*, called also *Primula variabilis*, a hybrid derived from *Primula vulgaris* and *P. officinalis*. This plant is true to seed, and is met with everywhere throughout almost the whole of Europe in company with both parent-species. In some districts of France it is found also in places where one or other of the latter species does not grow at all, and even where both are absent. Our fourth example, *Linaria stricta*, is the hybrid of *Linaria striata* and *Linaria vulgaris*. It occurs in many places in the West of Europe, together with its progenitors, but in the South of France, in the neighbourhood of Montpellier, it is found growing with *Linaria striata* alone, whilst the other parent-stock, *L. vulgaris*, is never found in the district.

We shall have another opportunity of describing the way in which the lines of demarcation of the ranges of entire floras become displaced in consequence of the changes which the climate of a region is liable to undergo in course of time. These displacements of floral regions are, as a rule, the result of very slow and inconspicuous migrations on the part of the plants constituting the floras in question. The direction of migration is invariably towards the places whose climatic conditions agree best with the organization of the plants, and is, in the case of any one species, either an advance or a retreat, according to the nature of the circumstances which impel the species to migrate. The different plants of a flora do not all migrate in a host together. Some species abandon their former home entirely and establish themselves in a new locality more or less remote from it; others leave a few of their kind behind in the old settlement at isolated spots which happen to be in peculiarly favourable situations, and many succumb to the effects of the new conditions or to the hardships incidental to the migration, and so die out. These changes in the range of floras are naturally accompanied by all sorts of alterations in the social relationships of the plants concerned especially with regard to the co-existence of hybrids and their progenitors. It may happen that one or both parent-species are left behind, whilst the hybrid advances, or the hybrid may remain behind, whilst one of the parent-species advances; or, again, one of the parent-stocks or both may die out. The facts concerning these local displacements explain the phenomenon that species which, from their characteristics, may be looked upon as hybrids of two other species, occupy in each case a district which is separated, and often at a considerable distance, from the areas inhabited by the species supposed to be their progenitors. The characteristics of the kind of Sorrel named *Rumex Patientia* lead one to the conclusion that it is a hybrid derived from *Rumex aquaticus* and *Rumex crispus*. It is found, however, growing wild in Hungary and in Bosnia in parts where neither *Rumex aquaticus* nor *R. crispus* occurs at all. In Herzegovina there grows fairly commonly a *Micromeria* which has been named by one of my friends *Micromeria Kernerii*. So far as its characteristics are concerned it must be considered to be a hybrid of *Micromeria græca* and *Micromeria Juliana*; yet neither of these two species grows in Herzegovina at the present time, and they are not met with at any nearer spot than the part of Dalmatia which stretches westward from Herzegovina, and belongs to the area of distribution of the Mediterranean flora. In the little upland valleys of Planail and Plawen, which run down from the mountains of the Oetzthal into the valley of the Adige, there grows a *Pulsatilla* named *Pulsatilla nutans*. If it occurred in company with *Pulsatilla vulgaris* and *Pulsatilla montana*, all Botanists would be unanimous in looking upon it as the product of a cross between those two species. Yet *Pulsatilla vulgaris* and *P. montana* do not grow in the high valleys in question, but are first met with at a distance of many miles from them, the former in the Unterinnthal and the latter in the Vintschgau (a portion of the Adige valley).

Inasmuch as the last-mentioned cases have to do with processes which have taken place long ago they partly belong to the next chapter, where the genesis of

species in the past will be discussed. They here bring to a natural conclusion a series of examples adduced to show in what manner a genesis of new species may ensue in the present, and may have taken place in the past. No sharp line of demarcation is to be found between different epochs in this connection any more than in the case of any of the other phenomena which, in the aggregate, constitute the history of species.

Now that it has been shown how new species arise from hybrids, or, in other words, from the crossing of species in pairs, the question presents itself whether, in addition to this one method, there are not also others leading to the same result. In answering this question we must bear in mind that every permanent change in external form which is inherited by a plant's descendants must be preceded by a change in the constitution of the protoplasm, and that so far as investigation has elicited the facts, the centre of the change is located exclusively in a particular protoplast which lies hidden in the ovary and there receives the spermatoplasm. The stimulus which causes the change in this protoplast can only proceed from the spermatoplasm, and every speculation concerning the formation of new species must therefore be associated with the question whether in the intercrossing of plants of one species and in autogamy the protoplasm in the course of its journey to the ooplasm may, as a result of its exposure to new external conditions, undergo modifications of so fundamental a kind that its influence on the ooplasm is subject to corresponding variations. In the first place, it might be imagined that the pollinated stigmas do not always act in the same way upon the spermatoplasm of the pollen-cell. Reference has already been made to the fact that a stigma may sometimes be almost simultaneously dusted with the pollen of very different plants (see p. 404), but that it has the power of exercising a selection, and that in every case only one kind of pollen is induced to put forth tubes by which a real fertilization is accomplished. The other kinds of pollen upon the stigma are not known to have a direct effect upon the ovule. But that there is some interaction between them and the protoplasm in the cells of the stigma is evidenced by the fact that they swell up wherever they are in contact, and (as has been shown, p. 414) are frequently found developing pollen-tubes. Now it is possible that the reciprocal action of the contents of these pollen-cells and the contents of the stigmatic cells may produce some change in the latter, which is transmitted to the contents of those other pollen-tubes which are to enter into combination with the ooplasm. Such modification might conceivably affect the nature of the stimulus imparted to the ooplasm, and this alteration in the stimulus might be manifested in a change in the form of the individual arising from the fertilized ooplasm. The likelihood of all these possibilities and assumptions being satisfied is extremely small, but as no researches have yet been instituted into the matter, it cannot be dismissed with an unconditional negative.

In artificial crosses between different species of *Cirsium* it has often been noticed that pollen-cells taken from a single capitulum vary in their effects upon the stigmas of a second capitulum, inasmuch as the seeds produced by the different florets, though all fertilized with the same kind of pollen, yield dissimilar plants when

they germinate. The variation is limited, it is true, to the different degrees in which the seedlings resemble one or other of the parent-plants. If the cross is between two plants of the same species no such variation can occur, seeing that the plants crossed are alike in form. But there is still the question whether differences in the age, size, and luxuriance of growth of the individuals which cross may not have some influence on the result. So far as my experiments show, these differences have no effect on the genesis of new forms, and have no prospect of becoming permanent characters in the offspring. A poor stunted plant growing on dry soil may produce seeds which, on being planted in a good moist soil give rise, under favourable conditions, to well-developed plants capable of flowering luxuriantly. As is well known, the first flowers of an inflorescence are always much larger than those which subsequently open at the apices of the spike or raceme, or on the ultimate ramifications of the cyme as the case may be. Now, if the large earliest flowers are crossed one with another, and likewise the small latest flowers, and the seeds so obtained in each case are kept separate but reared under similar conditions, the plants produced from them do not differ in the slightest degree from one another, but in their turn bear flowers, of which the first are the largest and the last the smallest. Notwithstanding these results, however, I should not like, without further investigation, to deny the possibility of the specific constitution of the spermatoplasm undergoing some change as a result of external influences in the course of its development, whether during its imprisonment in anthers or antheridia or on its way to the ooplasm, or to say such change might not cause the descendants of the plants concerned to differ in form from the individual from which they sprang.

It has been established beyond all doubt that modifications of form directly induced by conditions of soil or climate are not hereditary, and that every change of form which persists in the descendants is only brought about as the result of a process of fertilization, or, in other words, that new species can only arise through fertilization. Herein lies also the solution of the marvellous phenomenon known as the alternation of generations, and of the question why plants in general flower and undergo fertilization. To these processes is due the genesis of new species. The propagation of plants, their multiplication and dispersal, may also be effected by means of brood-bodies, and as a matter of fact these processes are continuously operating on a vast scale. But the plants reproduced by brood-bodies retain the form of their ancestors unaltered, and no new forms arise in this way. Suppose that a locality is occupied exclusively by plants which multiply by brood-bodies only and do not change their form, and that in consequence of a change in the climate such species as are not adapted to the new conditions abandon their homes, or else languish and die out, the probability is that many of the vacated spots will remain unoccupied owing to there being no recruits in the neighbourhood, or from out its confines, that are better adapted to the new conditions. If, on the other hand, the area in question is inhabited by plants which reproduce sexually and which, by crossing one with another, produce descendants of diverse forms, there is

every probability that amongst the assemblage of new forms some will be better adapted to the new conditions when a change of climate occurs than those of the old species which are driven out thereby, and that these new forms will therefore be able to take the place of the latter.

It is only from this standpoint that we can properly understand the phenomena of the alternation of generations, the separation of the sexes, dichogamy, and all the rest of the wonderful floral contrivances, the object of which is to facilitate the crossing of two species during the first stage of flowering and only to allow of crossing between plants of one species, or of geitonogamy, autogamy, or cleistogamy in the event of no inter-specific crossing taking place. As a result of these contrivances, numberless new forms are continually being generated which are respectively adapted to all the most various conditions of soil and climate. So long as no change in climatic conditions takes place, the majority of these forms have very little chance of surviving and of naturalizing themselves as species amongst the plants already established in the same locality. But when, in consequence of a change of climate, the ranks of the species in possession of the ground are thinned through the abdication of many of those best adapted to the conditions of life previously existing, the real significance of the new forms which have arisen as a result of the sexual process is manifested in the fact of those which are best adapted to the new conditions taking possession of the spots vacated and settling down there as new species.

DERIVATION OF EXISTING SPECIES.

The plants preserved as fossils in former ages are not only the forerunners but the ancestors of the existing vegetation of to-day. There was no general rejuvenescence and extinction of organisms coincident with the beginning and end of the several "periods" of the history of the earth. The changes in the organic world, like those in the inorganic crust of the earth, were accomplished gradually by slow degrees, and the organisms of the present day are a continuation of, and have been slowly evolved from, those of former ages.

So far, there is little difference of opinion amongst naturalists; but as to the causes of the differences in form between the vegetation of the present and the past, the most various theories are held. Nor is this surprising, seeing how largely our conclusions are based on conjectures. And when the flood-gates of speculation are rolled back it is not always that the proven is clearly distinguished from the unproven. An import is attached to isolated facts which they do not merit, and—most mischievous of all—the existence of wide lacunæ in our knowledge is concealed, or these lacunæ are dexterously bridged over with unmeaning, high-sounding words and hollow phrases which, while astonishing us for the moment, leave us chastened and confounded. The confirmed mistrust aroused by these extravagances which obtains concerning all that bears on the derivation of species demands that we should devote a brief consideration to the prevailing theories, and especially to

such as bear upon the conversion of species of former times into those of the existing vegetation.

A change in the conditions of life has, according to a widely-spread view, been the immediate cause of a change in the vegetation. The altered conditions of life provoke new wants in the plant, and these new requirements have led to a transformation of their organs. Stimulated by use, the organs in question become enlarged and further developed; others, no longer of service, become smaller, atrophy, and disappear. It is the cumulative result of these small and almost imperceptible changes that in course of time becomes apparent. These structural changes are transmitted to the progeny, and with an increasing tenacity, the greater the number of generations which have been exposed to the altered conditions. This, the *theory of adaptations*, has provoked wide discussion and criticism. It is urged against it that, whether wild or cultivated plants be considered, it is only isolated or a few individuals, never the whole of the members of a species, which exhibit these variations and transmit them to their offspring. If these new characters are immediately due to the soil or climate, then all the individuals of a species, exposed to like conditions of growth (environment), should exhibit them and hand them on to their offspring. The permanence of the influence—and to this many naturalists and others attach great importance—is without significance in this matter. When a change is called forth—be it by an altered source of nourishment, by the influence of heat or cold, light or darkness, moisture or dryness—it must become apparent upon the growing plant, since a change in the plant stands to a change in the environment as effect to cause. If the cause ceases, so also does the effect, equally after the lapse of a year or a hundred years. But a much more potent criticism of the theory of adaptation is the result of a series of experiments which were carried out for the solution of these questions. From them we see that an altered environment calls forth certain changes in the plants submitted to it, but that these are not transmitted to the offspring, are not hereditary, and that the influences of soil and climate do not provoke a fundamental change in the constitution of the protoplasm. Influences of this sort can induce a diseased condition in a plant and can even kill it, but they cannot bring about a change which can be transmitted to the next generation. Though soil and climate play a most important part in the struggle of species and varieties for existence, and though the environment has a great influence on the origin of varieties and on the distribution and migration of plants—as the immediate stimulus to the origin of new and transmissible characters, and thus to the modification of species, change of environment is without significance.

Another theory dealing with the origin and modification of species is that known as the *theory of progressive transformation by inherent forces*. According to it, the impulse to change resides in the inherent tendency of all species to perfect themselves. This theory transcends all experience and depends on premises and draws conclusions essentially metaphysical in nature; it deals only in part with the results of scientific observation. It presupposes a creation of living

protoplasts endowed with the capacity to alter their constitution on their own initiative; and, further, that these alterations take place along predetermined lines in a direction leading from a lower to a higher platform; consequently the imperfect organism necessarily, in course of time, passes over into a highly developed, perfect one. Against this theory the following may be urged: The first assumption involves creation. The question is: Is it possible for a living protoplast to be formed from inorganic matter without the co-operation of already existing living beings? The question obviously concerns the present and future as well as the past, for what has happened once may again take place, for the forces of nature, according to the laws of the conservation of matter and energy, remain the same for all time. The discussion of this question resolves itself into this: whether a little bit of protoplasm can arise from inorganic matter, and after its origin can acquire the capacity of growing by the absorption of food from its environment, &c.; in a word, whether it can exhibit those changes and movements which we term life. When first organic compounds (formic acid, urea, sugar, &c.) were synthesized in chemical laboratories from inorganic substances like ammonia, carbonic acid, and water—compounds which formerly had only been produced as a result of the activity of living protoplasm—naturalists began to think that these things might take place in nature independent of already existing plants. It seemed possible that these substances might, under the uncontrolled forces of nature, unite and arrange themselves in the same manner as occurs within a vegetable cell. The tendency of matter to combine, which plays so important a part in nature, was pointed out, and especially the similarity between the structure of crystals and that of certain cells; the properties of finely-divided soil also were called to mind, how it absorbed gases, took up water in varying quantities, altered salt-solutions, separating certain of their constituents, and what was especially noteworthy, increased the capacity of many simple substances to combine. This was at a time when chief importance was attached to the chemical properties of protoplasm; it was thought that, once given the substance, it would form itself into cells like crystals. Of the ultimate structure of protoplasm and of the nucleus knowledge was as yet very incomplete. The tendency of that time was to explain all those phenomena which constitute life as the resultant of the various forces which form inorganic bodies, and to deny the existence of any wide gulf between the living and non-living world.

The experiments to produce living matter had all of them negative results. But this of course is no proof of its impossibility; for it can always be urged that wrong methods were followed, and improper conditions imposed. Nor, on the other hand, does it follow from the fact that hitherto living matter has never been known to originate independently of existing organisms, that its production is impossible. Since we cannot arrive at definite results by experiment, the investigator must depend on other considerations.

The second assumption of the theory of transformation from internal causes, that plants have the inherent capacity to modify their internal constitution and,

similarly, their external form spontaneously, has been so fully met by the observations recorded in the last chapter that it is hardly necessary to deal with it now at great length. I shall content myself with pointing out that it is impossible to give a natural explanation of such a phenomenon. Every variation presupposes a corresponding disturbance; for the acquirement of any new structural character the plan of construction must undergo some fundamental alteration. The naturalist is unable to grapple with the phrases "internal causes", "internal force", "force of transformation", "tendency to differentiate", "principle of progressive transformation", when attempting to explain variation in a natural manner upon mechanical principles. Nor is the likening of this transformation to the metamorphosis which every individual passes through at various periods of its existence at all to the point, since metamorphosis repeats itself with great constancy in every species according to the plan of construction which is laid down in the specific constitution of the protoplasm. That the protoplasm of any species should, in the absence of any impulse or stimulus from outside, be able spontaneously to alter its plan of construction contradicts all our experience of the normal action of natural forces. Even should we conceive vital force, the dormant energy of the protoplasm, to be converted into an active form, it could only give rise to movements which have their origin in the specific constitution of the protoplasm.

And now we come to the assumption that this inherent force of transformation is a progressive one, that it leads to a higher or more perfect development. But what is to be regarded as a higher development amongst plants? A tree with its brightly coloured flowers and luscious fruits seems more highly developed to the non-botanist than a low herb with inconspicuous flowers, or than the green filaments of a *Spirogyra* destitute of flowers. The supporters of the theory under discussion assert that the highest development is that which exhibits the greatest complexity of form, and in which division of labour is carried furthest. And in this assertion they do not essentially differ from the popular view. Complexity of form and division of labour are undoubtedly carried further in an Apple-tree than in the *Spirogyra* of the ponds and ditches. But it must not be forgotten that the differentiation of a plant-body into various tissues, the production of wood, bast, and cork in its stem, of cuticle, stomates, and hairs on its leaves, of various colouring-matters and aromatic substances in its petals, and of sweet juices in its fruits, stands in harmonious relation to the environment of the plant in question. Change the conditions, and imagine the Apple-tree submerged in a pond; it is no longer in harmony with its surroundings, its complexity of tissues, its wood, stomates, &c., are not so well adapted for these conditions as are the *Spirogyras* and Water-weeds equipped with organs of another type. The size of a plant is often—in the popular estimate—the indication of its high organization. A big plant gives the impression of possessing a more perfect development than a small one. But this criterion leads to no satisfactory result; it is sufficient to instance the case of certain huge sea-weeds (*Macrocystis*) of the southern seas, which exceed our greatest forest trees in height. Many Thallophytes, only visible under

the microscope, show a greater complexity of structure of their constituent cells than do many Flowering Plants; and, should especial importance be attached to this character, Diatoms and Desmids must be regarded as more highly organized than many small annual Composites. The idea of progressive development implies a recognition of that species of plant which is most highly developed and which stands upon the apex of the pyramid, or, at any rate, of the group of plants which has already reached the furthest point—is it the Aristolochiaceæ, Cannaceæ, Magnoliaceæ, the Orchids, the Composites, the Ranunculaceæ, the Papilionaceæ, or the Pomegranates? Any one who has studied carefully the structure of these plants knows well that it is impossible to make an estimate of this kind. In a book of Botany one group must be treated first and another last, but this does not necessarily imply that the last is the most highly developed; indeed the various writers of systematic works begin and end with the most various groups. Like the theory of adaptability, that of progressive transformations from inherent forces fails to give us a reasonable explanation of the variations which plants have undergone in process of time.

A third theory, based on the observations of modern times, is as follows: That variations of form in the offspring arise through crossing, from the union of two dissimilar protoplasts. This theory, based on the union of unlike forms, has been fully sketched out in the last chapter. It assumes the existence in former times of a vegetation rich in forms—an assumption amply justified by the fossil remains which have been preserved. New forms arose, not by a progressive development such as has been alluded to, but by a transformation or metamorphosis of those already in existence. It was from the union of existent types that incipient new species were produced. By the periodic recurrence of changes in climatic conditions the areas of plant-distribution have received continual displacements, and it was then that these incipient species or varieties were put to the test. Those well-suited to the fresh conditions settled down into new species. They replaced their less well-adapted ancestors in the plant-community, and they played the same part as these had formerly done. A change indeed is brought about; but not (on the lines of the theory of adaptability) as a direct result of climatic influences, nor from an inherent tendency to progressive development. It arises rather from a change in the specific constitution of the protoplasm in consequence of the crossing of unlike forms. In basing the transformation of species on a crossing of this nature we are relieved the necessity of picturing lacunæ in a vegetation as a result of climatic changes, or of any serious disturbance of the inter-relations of its various component forms. Bacteria and Moulds, Mosses and Lichens, Ferns, Grasses, Palms, and Coniferous Trees, have all of them a special function to fulfil in the great community of plants, and they are to a certain degree dependent on one another. Were one removed the whole would be affected, and it might well happen, did a given group come to speedy extinction, that the whole community of plants might suffer. But in every group at all times and in all places a reserve of new forms continually arises by crossing, so that this danger is averted. With climatic

changes, of the older, less fit forms some are extinguished, whilst young, new forms step into their places. Thus we see also that the conversion of Mosses into Ferns, of Ferns into Conifers, and of Grasses into Pinks, &c., as assumed by the theory of progressive transformation, would be a positive disadvantage to plants as a community, and that its tendency would be in the direction of anything but real progress.

It is important to recognize the fact that in the production of new forms by crossing, it is not especially such forms as are constituted to resist an anticipated change of climate that are produced. Of the forms which arise, some are fitted for a more inhospitable, others for a milder climate; but it cannot be said of any that they possess an assured future. Such only are able to maintain, propagate, and establish themselves, as are from their internal organization and external form in harmony with the prevailing climatic conditions of the moment. Those so constituted that they are unable to thrive under the given external conditions linger and become extinct; they are outstripped and overgrown by such as find the environment to their liking. Hence we speak of the struggle for existence. Plants in harmony with their surroundings are the victors, and they establish themselves upon the arena of this encounter. This, briefly, is Darwin's theory of Natural Selection, a theory which marks an advance upon all other theories of the origin of new species. Though many views may be held as to the precise manner of origin and transformation of forms, there can be no difference of opinion as to the significance of the struggle for existence and of the survival in this struggle of those forms best fitted by their organization to the circumstances of the environment.

THE SUBDIVISIONS OF THE VEGETABLE KINGDOM.

The fact that the savants of ancient times made no attempt to classify plants according to their structural characters is explained by their limited botanical knowledge. Their interest was restricted to such plants as were in use as drugs, poisons, and charms, to vegetables, fruits, and cereals, finally, to such as were of value for decorative purposes and as symbols of religious observances. Nor was the number of these plants considerable. Some five hundred forms were known to Theophrastus (300 B.C.), whilst Pliny (23-79 A.D.) records about twice that number. The characters of these few plants could be retained in the memory for the purposes of comparative investigations, and their recognition depended in large part upon the general impression gained in the ordinary intercourse with nature. Enumerations of plants were based far more on their medicinal or economic uses, on their hurtfulness and beneficence for mankind, than on any structural characters they might possess in common. Even in the herbals of the sixteenth century, containing, as they did, new descriptions and incomparable woodcuts, were the medicinal and economic properties of the various plants still especially emphasized; Botany was still almost exclusively the handmaiden of medicine and agriculture.

The first botanical writer to break with these old traditions was Clusius (1526-1609); he described plants as he observed them, quite apart from their value to man. Clusius, though a Belgian, spent many years of his life at Vienna, and thoroughly explored the Flora of Austro-Hungary; previously he had investigated the plants of Spain and Portugal. To England he paid more than one visit, and received many exotic plants from Sir Francis Drake, the voyager. In his *Rariorum Plantarum Historia*, published originally in 1576, we find the first attempt to classify plants according to their similar characters. In separate books he deals with trees, shrubs, and under-shrubs, bulbous plants, sweet-smelling flowers, scentless flowers, poisonous, narcotic, and acrid plants, with plants having a milky juice, and with Umbellifers, Ferns, Grasses, Leguminosæ, and certain Cryptogamic plants. In those days some 4000 plants were distinguished by Botanists, and the want of some system of classification was gradually felt. The groups of Clusius and his contemporaries were inadequate, and the system of Cesalpino (1519-1603), published in the first book of his *De Plantis Libri XVI* (1583), failed to obtain the recognition it undoubtedly deserved—perhaps because it was only sketched out in outline and lacked a full and detailed rendering. Cesalpino was the first to convert observation into real scientific research; he drew attention to the more hidden organs of plants, to the position of the seeds, the number and mode of insertion of the cotyledons, &c., to the presence or absence of flowers.

It is to Tournefort (1656-1708), a Frenchman, that we owe the first complete review of known plants in synoptical form. In his *Institutiones Rei Herbariæ* (published 1700) 10,146 species of plants are distinguished and arranged in 698 genera, which again are assembled under 22 classes. Classes 1-15 include herbs and under-shrubs, 16 and 17 flowerless plants (Cryptogams), and 18-22 shrubs and trees. The herbs, shrubs, and trees are distinguished by the form of their flowers, especial importance being attached to the presence of calyx and corolla, to the regularity or irregularity of the flower, and to the petals—whether they are free or united with one another. Not long afterwards Linnæus produced a classification of plants based on the distribution of the sexes, and especially upon the number of the stamens in the flowers. The terms species and variety, genus and class, were more clearly and intelligibly defined than heretofore, and his 1050 genera were included under the 24 classes already enumerated (p. 288). The Linnean classification, known as the Sexual System, enjoyed an unprecedented recognition. It constituted a well-arranged summary of a great mass of scattered observations, and made it possible for species to be identified by means of concise descriptions. It was not the fault of this accomplished and renowned naturalist if a greater importance were attached to his system than he himself ever intended. Linnæus never regarded these 24 classes as real and natural branches of the vegetable kingdom, and expressly says so; it was constructed for convenience of reference and identification of species. A real natural system, founded on the true affinities of plants as indicated by their structural characters, he regarded

as the highest aim of botanical endeavour. He never completed a natural system, leaving only a fragment (published 1738).

The credit of actually founding a natural system of plants is usually attributed to Bernard de Jussieu (1699–1777) and his nephew Antoine Laurent de Jussieu (1748–1836). For many years this system only found expression in the laying out of the beds in the Botanic Garden of Trianon (at Versailles); it first became generally known some thirty years after its inception, when the younger de Jussieu published his *Genera Plantarum* (1789). A hundred families of plants are distinguished and grouped under fifteen classes, which, in their turn, fall under three main co-ordinated divisions (Acotyledones, Monocotyledones, Dicotyledones). The three main divisions¹ are founded upon the structure of the embryo at germination. In the Acotyledones the embryo consists of but a single cell and is destitute of cotyledons, in the Monocotyledones it is multicellular and provided with one cotyledon, whilst in Dicotyledones there are two cotyledons. The Acotyledones are equivalent to the Cryptogamia of Linnæus (his 24th class, cf. p. 290) and constitute the 1st class of the new system. The Monocotyledones fall into three classes according to the relative position of the stamens to the ovary (Monohypogynæ, Monoperigynæ, Monoepigynæ). The Dicotyledones are first subdivided into three groups according to the structure of the perianth, viz., into those destitute of petals (Apetalæ); those with distinct calyx and corolla, the petals being united (Monopetalæ); and those also having calyx and corolla, with all the petals free from one another (Polypetalæ). Each of these groups is subdivided into three classes, based on the relative position of stamens to ovary (in the case of the Monopetalæ of corolla to ovary). Since in the Dicotyledones with unisexual flowers it was impossible to indicate the relative position of stamens and ovaries, a special class (Diclinales irregulares) was set aside for them. The institution of this last class does not mark an advance towards a natural system; whilst the limitations of the other classes in respect of the relative positions of stamens to ovary is cumbrous and unnatural, still they are less artificial than those of the Linnean Sexual System. The distinctive features of the system of de Jussieu are the broad characters upon which the families are based—the whole structure of the plant being taken into consideration—and especially the recognition of Monocotyledons and Dicotyledons as equivalent groups of Flowering

¹ A. L. DE JUSSIEU'S SYSTEM OF 1789.

A. L. DE VOSSE'S SYSTEM OF 1793.			Class.			
Acotyledones			I.			
Monocotyledones	{	Stamina hypogyna.....	II.			
		perigyna.....	III.			
		epigyna.....	IV.			
Dicotyledones	{	Apetals.....	Stamina epigyna.....	V.		
			perigyna.....	VI.		
			hypogyna.....	VII.		
	{	Monopetals.....	Corolla hypogyna.....	VIII.		
			perigyna.....	IX.		
			{	epigyna {	Antheris connatis.....	X.
					distinctis.....	XI.
	{	Polypetals.....	Stamina epigyna.....	XII.		
			hypogyna.....	XIII.		
			perigyna.....	XIV.		
	Dielines irregulares			XV.		

Plants. A. P. De Candolle¹ (1778–1841) in his *Théorie Élémentaire de la Botanique, ou Exposition des Principes de la Classification naturelle* (published 1813), distinguished between cellular and vascular plants (Cellulares and Vasculares). The former are constructed of cells alone, whilst in the latter vessels also are met with. The cellular plants were divided into those without leaves (Cellulares aphyllæ) and those provided with leaves (Cellulares foliaceæ). The vascular plants were divided according to anatomical views current at the time into those in which the vascular bundles were scattered through the stem and were supposed to originate from within (Endogenæ), and into those in which the vascular bundles were arranged in a ring and were added to from without (Exogenæ). The group Endogenæ included the Vascular Cryptogams (Endogenæ cryptogamæ), forms destitute of flowers, and the Monocotyledons of de Jussieu (Endogenæ phanerogamæ). The Exogenæ, the equivalent of de Jussieu's Dicotyledones, were divided into those with a simple perianth (Monochlamydeæ), and those with a distinct calyx and corolla (Diplochlamydeæ). The latter are further subdivided into three groups: the Corollifloræ, in which the petals are united into a continuous corolla; the Calycifloræ, in which the petals are inserted upon the calyx; and the Thalamifloræ, in which the petals are free and inserted upon the floral receptacle. Although De Candolle based his system upon characters essentially different from those used by de Jussieu, and although in both systems there are many deviations in the limitations of the classes and families, there is on the whole an agreement in many essential particulars. Especially may we note the recognition of Monocotyledons and Dicotyledons (though under different names) as the two contrasting main divisions of Flowering Plants. And further, that the Cellular and Vascular Cryptogams are sharply distinguished from one another. The main groups, the Cellular and Vascular Cryptogams, the Monocotyledons and Dicotyledons, are met with (under various names) from this time onwards in all later schemes of classification; and, so far as we can tell, appear to constitute so many natural groups—groups, that is, of which the members are all more nearly allied by descent to one another than to the members of the other groups.

Following De Candolle many Botanists elaborated schemes of classification during the first half of the nineteenth century; these included Reichenbach, Oken, Agardh, Martius, Brongniart, Bartling, Endlicher, Lindley, and many others. To the non-botanist, recognizing the fact that there can be but one real natural system

¹ A. P. DE CANDOLLE'S SYSTEM.

I. VASCULAR OR COTYLEDONOUS PLANTS.

1. EXOGENÆ OR DICOTYLEDONS.

- A. Perianth double (calyx and corolla).
Thalamifloræ (petals distinct, inserted on the receptacle).
Calycifloræ (petals free and inserted on the calyx).
Corollifloræ (petals united together).
- B. Monochlamydeæ (perianth simple).

VASCULAR OR COTYLEDONOUS PLANTS

(continued).

2. ENDOGENÆ OR MONOCOTYLEDONS.

- A. Phanerogams (= true Monocotyledons).
- B. Cryptogams (= Vascular Cryptogams and Naiadaceæ).

II. CELLULAR OR ACOTYLEDONOUS PLANTS.

- A. Foliaceæ (leafy=Mosses and Liverworts).
- B. Aphyllæ (not having leaves=Thallophytes).

of plants, this great variety of specialist opinion is somewhat surprising, and tends to shake his confidence in all botanical systems. But it must be remembered that in the development of a natural system the imagination plays a much more important part than in the elaboration of an artificial one, nor can prevailing currents of thought, or the particular habit of mind of the observer, be without their influence. Very prominently does this appear in the case of the Botanists who came under the influence of what has been termed nature-philosophy during the early portion of this century. Thus Reichenbach and Oken proposed systems which can only appear to us absurd; but it would be wearisome and useless to follow their absurdities in detail.

The system of classification proposed by Endlicher¹ (1805–1849), and published in his *Genera Plantarum secundum ordines Naturales disposita* (published 1836–1840) is based on the systems of de Jussieu and De Candolle. In it 6838 genera, arranged in 277 families or orders, are included. Here for the first time are the Coniferæ and Gnetaceæ distinguished as a special group, and designated as Gymnosperms. Here also is that group of cellular plants known as the Thallophyta carefully distinguished into three series, the Algæ, Lichens, and Fungi. But we still find these groups treated as equivalent to the Horse-tails, Ferns, Lycopods, &c.; so also with the Gymnosperms, they are not treated as a distinct subdivision, but only as a class of Dicotyledons (*Acramphibrya*), the other classes of which are the *Apetala*, *Gamopetala* (= *Monopetalæ*), and *Dialypetala* (= *Polypetalæ*).

In fairly recent times Bentham and Hooker,² in their well-known *Genera Plantarum* (published 1862–1883), follow essentially the systems of De Candolle and Endlicher. They assemble all flowering plants (100,220 species) into 8417 genera, and these under 210 families or orders. Of these orders 3 belong to the Gymnosperms, 35 to the Monocotyledons, 36 to the Monochlamydeæ, 46 to the Gamopetalæ, and 90 to the Polypetalæ.

¹ ENDLICHER'S SYSTEM.

I. THALLOPHYTA (no opposition of stem and root).

PROTOPHYTA.

Algæ.
Lichenes.

HYSTEROPHYTA.

Fungi.

II. CORMOPHYTA (opposition of stem and root).

ACROBRYA (stem growing at the point only).

Anophyta (Liverworts and Mosses).
Protophyta (Vascular Cryptogams and Cycads).
Hysterophyta (certain parasites, Balanophoræ, Rafflesiaceæ, &c.).

II. CORMOPHYTA—Continued.

AMPHIBRYA (stem growing at the circumference).
Includes Monocotyledons.

ACRAMPHIBRYA (stem growing at both point and circumference).
Gymnosperma (ovules naked, fertilised directly from the micropyle).

Apetala (Perianth 0, rudim. or simple).
Gamopetala (Perianth double, petals united).

Dialypetala (Perianth double, petals free).

² THE MAIN DIVISIONS OF BENTHAM AND HOOKER'S SYSTEM

(FOR FLOWERING PLANTS ONLY).

DICOTYLEDONES.

Polypetalæ.
Gamopetalæ.

DICOTYLEDONES—Continued.

Monochlamydeæ.
Gymnosperma.

MONOCOTYLEDONES.

Though the grouping of Dicotyledons (according to the characters of the perianth) into Monochlamydeæ (= Apetalæ), Gamopetalæ (= Monopetalæ), and Polypetalæ (= Dialypetalæ), is very generally recognized to be an unnatural one, it is no easy task to replace it by a better one. The families belonging to the great group Dicotyledons show the most multifarious relations to one another. An arrangement, based on the assumption that these families have been developed one from another, is not discoverable; whilst an arrangement in linear series is as unnatural as one resembling a tree with its branches. Very appropriate was Linnæus's comparison of the limitations of these families with the dovetailing of the frontiers of countries on a map. One family stands in touch with two, another with three, others again with four or more allied families. This contact or relationship occurs on the most various sides. Some families are extremely large and comprehensive, others relatively small, and, as it were, jammed in between them; whilst others resemble scattered islands off the coast of a continent.

Well worthy of consideration is the system of Alexander Braun,¹ published in 1864 in Ascherson's *Flora der Provinz Brandenburg*. Though the division of Dicotyledons into Apetalæ, Sympetalæ, and Eleutheropetalæ suggests at first sight the classifications of de Jussieu and Endlicher, there is a difference, and an important one. A large number of the families included by the older Botanists in the Apetalæ are here placed in the Eleutheropetalæ. With the Eleutheropetalæ are ranked those plants "in which calyx and corolla are typically present, the latter consisting of separate petals". They are ranged in 24 Alliances or Cohorts—Hydropeltidinæ, Polycarpicæ, Rhœadinæ, Parietales, Passiflorinæ, Guttiferæ, Lamprophyllæ, Hesperides, Frangulinæ, Æsculinæ, Terebinthinæ, Gruinales, Columniferæ, Urticinæ, Iricocceæ, Caryophyllinæ, Saxifraginæ, Julifloræ, Umbellifloræ, Myrtifloræ, Thymelæinæ, Santalinæ, Rosifloræ, Leguminosæ. In recent times we have the systems of Eichler and Engler. They follow the lines laid down by Alexander Braun, but, carrying his method further, the group Apetalæ (or Monochlamydeæ) is entirely abolished, its members being referred in part to the Sympetalæ, and in part to the Eleutheropetalæ (= Archichlamydeæ of Engler).

During the last fifty years our knowledge of the Cryptogams constituting the group Thallophyta (founded by Endlicher, *cf.* foot-note, p. 604) has increased by leaps and bounds. Several attempts have been made to bring together the results of the various researches upon this group, and to utilize them for classificatory

¹ ALEXANDER BRAUN'S SYSTEM.

I. BRYOPHYTA.

1. Thalloidea (Algæ, Lichens, and Fungi).
2. Thallophyllodea (Characeæ, Mosses, and Liverworts).

II. CORMOPHYTA.

1. Phyllopterides (Ferns and Equisetums).
2. Maschalopterides (Lycopods).
3. Hydropterides (Rhisocarps).

III. ANTHOPHYTA (Flowering Plants).

- A. GYMNOSPERMÆ (seeds exposed).
 1. Frondosæ (Cycads).
 2. Acerosæ (Conifers).
- B. ANGIOSPERMÆ (seeds in an ovary).
 1. Monocotyledones.
 2. Dicotyledones.
 - a. Apetalæ.
 - b. Sympetalæ.
 - c. Eleutheropetalæ.

purposes. The old division into Algæ, Fungi, and Lichens, based on the presence or absence of chlorophyll and on the mode of life of the forms in question, has been by many authors abandoned. Cohn in 1872 divided the Thallophytes, according to their methods of reproduction, into seven groups: Schizosporeæ, Zygosporæ, Basidiosporæ, Ascosporeæ, Tetrasporeæ, Zoosporeæ, and Oosporeæ. Sachs, in 1874, following somewhat similar lines, made four classes: Protophyta, Zygosporæ, Oosporeæ, and Carposporæ, in each of which groups both chlorophyll-containing (Algæ) and colourless forms (Fungi) occur, as may be seen by a perusal of the classification quoted below.¹ Goebel (1882) returns in part to the older method and distinguishes between Algæ and Fungi; but with these as groups of equal systematic importance he ranks the Myxomycetes, Diatomaceæ, and Schizophyta. The Algæ he divides into Chlorophyceæ (Green Algæ), Phæophyceæ (Brown Algæ), and Rhodophyceæ (Red Sea-weeds); and the Fungi into Chytridiaceæ, Ustilagineæ, Phycomycetes, Ascomycetes, Æcidiumycetes, Basidiomycetes. Warming (1884) returns completely to the older method, dividing the Thallophytes into Algæ and Fungi, ranking the Myxomycetes with the Fungi, and the Diatoms and Schizophyceæ with the Algæ. The balance of opinion at the present time, largely swayed by the views and researches of Brefeld upon the Fungi, favours a grouping of the bulk of Thallophytes into Algæ and Fungi. Brefeld regards the various families of Fungi as more intimately related amongst themselves than are these families to corresponding families of Algæ. That Fungi have arisen from Algæ at some remote period, and have then amongst themselves undergone development along various lines, is very generally held; but the view that the different families of Fungi stand in near relationship to the several algal groups—as indicated, for instance, in the system of Sachs, (*cf.* foot-note below)—is not at present the prevalent one. And amongst the Algæ, also, the attempt to classify the various forms into families according to the relative simplicity or complexity of their organs of reproduction (as Sachs suggested) no longer finds general favour. Amongst the Algæ we find a number of extensive

¹ SACHS'S CLASSIFICATION OF THALLOPHYTES.

I. PROTOPHYTA.		
<i>Containing Chlorophyll.</i>		<i>Not containing Chlorophyll.</i>
Cyanophyceæ.		Schizomycetes.
Palmellaceæ (in part).		Saccharomycetes.
II. ZYGOSPORÆ.		
	<i>Conjugating Cells Motile.</i>	
Pandorinæ (Hydrodictyæ).		Myxomycetes.
	<i>Conjugating Cells Stationary.</i>	
Conjugatæ.		Zygomycetes.
III. OOSPORÆ.		
Sphæroplea.		
Vaucheria (Coeloblasteæ),		{ Saprolegniæ.
Volvocinæ.		{ Peronosporæ.
Edogonæ.		
Fucoidæ.		
IV. CARPOSPORÆ.		
Coleochætæ.		Ascomycetes (including Lichens).
Floridæ.		Æcidiumycetes (Uredinæ).
Characæ.		Basidiomycetes.

groups, within the limits of each of which all stages of complexity in reproduction occur. The attempt to string together forms agreeing in reproductive methods makes it necessary to break up groups which on general grounds seem to be natural families. And as it is a natural system that we are striving after, systems like that of Sachs (which may be compared to the artificial sexual system of Linnæus) must be abandoned. That the publication of the Sachsian system in his widely-read "Text-book" has done great service to Botany there can be no doubt; it has stimulated thought and observation, and has led more speedily than would otherwise have been the case to the establishment of broad and probably sound views as to the relations of the Thallophytes. However, the Myxomycetes, approaching as they do certain groups of the animal kingdom, are kept apart from the rest of the Thallophytes in the most recent system.

The classification of plants according to their similarity of structure—species into genera, genera into families or orders, families into alliances or cohorts, these into classes, and classes into two chief branches or phyla, the Cryptogams and Phanerogams—leads to the presumption that these two chief branches have arisen from a common stock, have diverged from a common stem. A consideration of all animal and plant forms similarly leads us to the belief that the main stems of the Animal and Vegetable Kingdoms, respectively, meet at their points of origin. By studying systems of classification drawn up on paper and restricted to two dimensions of space, we involuntarily conceive the classes and orders of the vegetable kingdom, as a tree which continually branches, finally ending in thousands of twigs which represent the various species. Such is, rightly or wrongly, the conception of all Botanists who have concerned themselves with the construction of a natural system. They only differ in so far that some regard the Thallophytes as standing at the base, and derive from these the Liverworts and Mosses, from these the Ferns, &c., and so on to the Gymnosperms and Angiosperms; whilst others make a subdivision of the main trunk at once into Cryptogams and Phanerogams, each of these continually branching according to the various classes and families. Others again, whilst conceiving the whole vegetable kingdom as having a common origin, regard this as the centre of a sphere, and that the several phyla and classes radiate out from this, producing numerous branches and twigs at the surface of the sphere. Each of these hypotheses presupposes, in the first instance, the existence (or spontaneous generation) of a few Thallophytes of extremely simple structure which have become differentiated, *i.e.* given rise to more complex offspring which form the beginnings of the branches of the tree. To this kind of development of a tree-structure, the terms *Phylogenesis* or *Phylogeny* (from *φυλη*, a tribe; and *γενναι*, to produce) is given. Obviously, not only the original forms possess the capacity of differentiating, but their offspring also, and so on through the entire tree. But views are divided as to whether this continued differentiation follows a predetermined plan, is due to definite inherent forces, or whether it may not be restricted in this sense and due to other and external causes.

That a natural system has been evolved along lines resembling the ramifications of a tree, which commenced with simply organized structures and terminated with the most complex ones, finds a certain confirmation when the history of development of the individual (ontogeny, from *ὄν*, *ontos*, being; and *γεννᾶν*, to produce) is compared with its position upon the phylogenetic tree. As we know, the greatest of all flowering trees begins its existence as a single protoplasmic mass. This surrounds itself with a cell-wall and increases in size and complexity at the expense of nutriment derived from its environment. Gradually cells and tissues arise and the young organism becomes segmented into an axis and appendages. These, again, assume the most varied forms corresponding to a subdivision of labour. Ultimately the uppermost and last-produced members of the plant are transformed into flowers and fruits. It is thought that, just as a plant is gradually differentiated in this way so have all plants undergone a similar transformation, step by step. The egg-cell, the starting-point of the individual, may be compared to a Myxomycete, the cell-complex which arises from the egg-cell after fertilization to a Thallophyte, the segmented axis and appendages of the seedling to a Vascular Cryptogam, and the complete plant-body, finally, to a Flowering Plant.

This comparison, like so many others which captivated the imaginative faculties in the days of the speculations of nature-philosophy, has found many adherents; indeed, it has served as dogma and guiding light in many investigations. But it is difficult to harmonize it with other theories well-proved by experience. The main burden of this comparison (known as the "Recapitulation-theory") is that the vegetable kingdom as a whole has undergone a developmental history and transformation resembling that of a single member of the group of Flowering Plants. But first it must be asked, what is the meaning of metamorphosis in the individual, and what object has been attained by it? Though the actual processes taking place in the living protoplasm in metamorphosis are unknown, this much seems certain: That these changes occur along lines sufficiently well indicated; that the fashioning of the successive stages of any given species is accomplished according to a definite plan; that external influences, such as soil and climate, do not permanently affect this plan; and that consequently the plan of construction of these successively appearing stages is laid down in the protoplasm itself. The ultimate object of metamorphosis in plants is the production of fruit; and with the formation of an ovary the metamorphosis ends, the fertilized egg-cell beginning the metamorphosis all over again, *i.e.* it is the starting-point of a series of transformations along identical lines. And this applies equally to the Apple-tree and to the Palm, to the Pine, the Horse-tail, the Moss, the Bladder-wrack, Stonewort, to the Mould, and to the simplest of green Algæ. Only in the last-named forms are the intermediate stages fewer than in the first-named. But it will hardly be suggested that the latter have not on this account attained the end in view. Simple plants whose fertilization and fruit-formation is accomplished under water, whether it be on inundated land, in the mud of a river, or at the bottom of a lake, attain this end without a complex metamorphosis of petals and stamens; whilst many

of the denizens of the ocean have no need of segmentation into stem and leaf. Indeed, such a metamorphosis for this purpose would be a disadvantage, anything but a progressive development. Similarly is it inconceivable, from all we know of the relations between external conditions and the form of an organism, that a Fern (for instance), unable to accomplish its fertilization in dew or rain-water, should in consequence depart from its usual habit and strike out a new line of metamorphosis. Thus we may conclude¹ that the development of the individual (Ontogeny) cannot be regarded as an epitome of the ancestral history or line of descent of that individual, and, further, that ontogeny gives no support to the assumption of a ramifying phylogenetic tree starting with simple forms and ending with complex much-differentiated ones.

The results of developmental investigations showing a marked similarity in the form of organs serving similar purposes in the most different groups of plants have been brought forward in support of the assumption that Flowering Plants have arisen from simple Cellular Plants by a series of progressive transformations. Though these organs are in some groups of more simple, in others of more complex structure, their similarity is unmistakable; it is upon this that the view is widely based that organisms exhibiting similar organs have been derived from one another. But this inference is inadmissible. The similarity in question finds a simpler explanation as the expression of the attainment of a common object. Thus fertilization consists in the coming together and uniting of two portions of protoplasm which have originated at a distance from one another; the similarity of ways and means in attaining this object are obvious. In one case water is employed as a means, in another the air. There is, truly, a difference in detail, but the general similarity remains. From this general similarity all we are justified in inferring is that the organisms in question all reproduce themselves by fertilization, not that they have a common origin.

This conclusion leads to the question whether, in view of the diversity of the organs of fertilization, several distinct stems of plants may not have co-existed all along. We know from observation and experiment that new forms do not as a rule arise from offshoots, but from fruits. New groups of plants might thus (so it was said) arise from existing ones solely by the sexual method. Complex Thallophytes might arise from the fruits of simpler ones, Ferns from the fruits of Mosses, and so on. Assumptions of this kind belong to a period at which the phenomena of fertilization and fruit-production, especially in the Cellular Plants, were only very imperfectly understood. No Botanist nowadays would suggest the possibility of a *Spirogyra* or a *Ulothrix*, or an *Edogonium*, or a Stonewort, arising from the fruit of a *Vaucheria*. It might well happen that a new species could arise by the crossing of two dichogamous species of *Vaucheria*, but this new form would be essentially a *Vaucheria*, and its methods of fertilization would be essentially similar to that of its parent-forms. It is likewise as impossible for the male protoplasm of a *Vaucheria* to enter the chamber in which the conjugation of the

¹ See editorial note prefacing this volume.

sexual cells of *Spirogyra* takes place (cf. vol. i. Plate I. fig. 1), or for this spermato-plasm to fuse with the gametes of *Ulothrix* (cf. p. 49), as for the gametes of *Ulothrix* to enter and fuse with the egg-cell of a *Vaucheria*; no new group of plants could have arisen in this way. We may conclude then that plants belonging to groups with a marked diversity in their sexual characters have not arisen from one another, but belong to stems which have co-existed as distinct types from the first.

Nor must we omit to notice the observations which have been made in regard to symbiosis and the inter-relations of green and non-green plants. It has already been pointed out (vol. i. pp. 263, 264) how that the continuation of plant-life, and indeed all life, is dependent on the activity which saprophytic plants exhibit in the decomposition of dead organisms. Green plants could not exist independent of colourless saprophytes, nor these latter without green plants.

This must ever have been the case, and it must so remain.

We may then draw another conclusion, viz. that those colourless plants which by their activity bring about the decomposition of green plants cannot have arisen from green plants,



Fig. 365.—*Spirophyton* from the Upper Devonian.

but that from the beginning they have belonged to a distinct stem.

It is to Palæontology that we must look for the most trustworthy solution of the question as to whether numerous plant-stems have existed side by side from the first, or whether the groups which at present co-exist have in process of time branched forth from a single stem. Were it a fact that those forms which show a far-reaching division of labour, and a complex structure of organs, which we term "higher plants", have arisen from others of very simple mode of life and possessing a simple structure and which are known as "lower plants", then should we expect the earth to have been covered formerly by lower plants alone. And then, following this epoch, would have come a time when plants would have existed which might have served as the starting-points of the later-appearing distinct groups. We should expect to find in those strata of the earth's crust regarded by geologists as the oldest of all nothing but the remains of very simple Thallophytes, then, following these, Wracks, Red Sea-weeds, and Lichens, and after these Stoneworts (*Chara*), Mosses, or some other type of plant which, having given rise respectively to Stoneworts and Mosses, has, after this differentiation, become extinct.

From the graphite, which is looked upon as the oldest trace of vegetable life on the earth, unfortunately we obtain no conclusive evidence on this matter. From its presence on slate mountains together with crystalline limestone and pyrites

we might conclude that it originated from plants adhering to the limestone reefs formed by animals or from sea-plants which lived on the borders of these limestone cliffs. Where graphite is found in greatest quantity one is tempted to think it might have been derived from peat moors. As we have said, all these are merely suppositions, for since the carbon, lime, and silicates have become crystalline all the points for the determination of the families to which the graphite-forming plants belonged are lacking. It might be noted here, by the way, that although graphite does indeed furnish the oldest traces of plant-life on the earth this does not prove that the plants which gave rise to it were necessarily the first which



Fig. 366.—*Riella helicophylla* growing under water. Enlarged.

existed there. It is doubtful whether the rock which is associated with graphite formed the first hard crust of the earth. Much more probably this rock was composed of other broken rocks just as it has itself been again demolished, furnishing the material for new strata.

The shapes of vegetable remains from palæozoic formations are fairly easily recognizable. Those which were formerly regarded as fossil Sea-wracks have indeed been more recently interpreted as the trails of worms and medusæ, but some of them are without doubt the remains of Sea-wracks. The only other known lowly plant which at that time had an aquatic habit is the curious *Spirophyton*, the so-called Cock's-tail Alga (see accompanying fig. 365). This, though some regard it as of purely inorganic origin, may perhaps be regarded as a submerged Liverwort; at any rate it is not without resemblance to *Riella Reuteri*, which at the present time lives in the Lake of Geneva, and to the Algerian *Riella helicophylla* (see fig. 366). No trace is to be found of Thallo-

phytes which may have existed on land, but we have huge tree-like Vascular Cryptogams with trunks, fronds, and leaves which are to be placed side by side with our present-day Equisetums, Ferns, and Lycopods. Cycads and Conifers also are not absent from the Coal Measures. No Angiospermous flowering plants have hitherto been demonstrated in these strata, but it would be foolish to regard this fact as a proof that neither Thallophytes nor Angiosperms flourished at this period. That which has been preserved to us from this time certainly forms but a small fraction of the old vegetation, and is restricted apparently to the flora of peat-moors which were just as poor in species and just as monotonous as they are to-day. The plants which at the present time predominate on the moors are still the Equisetums, Ferns, Lycopods, and Conifers, and, in tropical regions, the Cycads; only a few species from each group, but standing in thousands side by side and aggregated into dense communities. Anyone who has worked out the history of these moors knows that the soil must have been prepared for these plants by other growths. *Equisetum limosum*, *Aspidium Thelypteris*, *Lycopodium inundatum*, &c., do not flourish in soil poor in humus; in order to obtain their requisite food and to develop they require soil which is saturated with the dead remains of earlier settlers. Experience tells us that the plants which appear as the first inhabitants belong to widely different groups (see vol. i. p. 268). Now if we hold to the view that the formation of peat-moors in long-past ages occurred just as in the present day, we must assume that the colonies of Equisetums, Ferns, Lycopods, and Cycads were preceded by other plants which, as the first settlers, prepared the soil. We cannot indeed determine from the surviving remains to which groups these first settlers belonged; but, looking back on the history of our present peat-moors, it seems not improbable that among them were both Thallophytes and Angiospermous flowering plants.

The fact that the fossil remains of Equisetums, Lycopods, and Cycads, which spread so widely over the peat-moors of palæozoic times, have reached us in such good condition is explained by the presence of humus-acids, which are formed universally in the peat (see vol. i. p. 263). There are four conditions which render it possible for a plant to be preserved as a fossil: humus-acids form the first; the second is the resin which exudes from the pine-wood and forms amber; the third is mud and sand brought by floods; and the fourth the silicification and calcification of the cell-wall or the formation of a lime incrustation which is precipitated from calcareous water on to the various parts of the plant. It is certain that these four conditions have always been effective, but it is doubtful whether all the fossils formed in the fourth manner at all periods have remained. For many older strata have long been destroyed and used in the building up of younger layers, and many risings and sinkings of these strata have taken place. It would indeed be difficult to find a single place on the earth's surface which has not been repeatedly above and under the sea. Much that might lead us to definite conclusions at present lies inaccessible to us, covered with immense masses of water at the bottom of the sea, and the view has actually been suggested from studies made on the few accessible

and closely investigated spots on the earth's surface that the fossil remains found there are not more than a minute fragment of the vegetation of periods long elapsed.

With these remarks we might mention that it is not beyond the range of possibility that, in addition to the Vascular Cryptogams, Cycads, and Conifers growing on peat-moors, plants of other habitats, especially those of fresh and salt water, or perhaps of sand-dunes and river-banks, might be found in the strata of palæozoic times. But no one would doubt that among these would be Angiospermous Phanerogams, and this throws some light on plant remains which have come to us from the mesozoic period. For example, in the upper layers of the chalk we find, in addition to the plants of peat-moors, the inhabitants of a luxuriant forest-flora of Angiospermous flowering plants. There are Planes, Birches, Beeches, Oaks, Poplars, Willows, Fig and Laurel trees, Maples, Ivy and other Araliaceæ, Bread-fruit trees, Tulip-trees and Magnolias, Cherry-trees, and Leguminosæ of the division Cæsalpinieæ, Palms, Rushes, and Grasses. If we do not believe in the theory that these Angiosperms were first created in the mesozoic period, and still less in the greater marvel that they have sprung from the Vascular Cryptogams, Cycads, and Conifers, we are forced to the conclusion that they too must have existed as far back as the palæozoic time. It is to be specially noted that not the slightest trace of intermediate or transitional forms which might connect the aforesaid Angiospermic Phanerogams with the Gymnosperms or with the Vascular Cryptogams has been found. One leaf is immediately recognized as belonging to a Tulip-tree, a second to Maple, a third to a Fig-tree, a fourth to a Palm, &c., but no plant has been discovered anywhere which would perhaps form a connecting link between the Palms or Figs and the Conifers or Vascular Cryptogams.

Even a cursory glance at the plant-forms named shows that they were members of mixed forests. It may be assumed, however, that other plant communities peopled the earth at the same time as these forests. The rocky terraces and boulders, as well as the flat dry land, were certainly not destitute of vegetation. Nor is it surprising that no fossil remains of the inhabitants of these places have remained. The under-shrubs and herbs of a dry soil decompose immediately after their death, and leave behind only formless humus, which mixes with the soil. Just as little fossil remains will reach posterity of the Lichens and Mosses, Pinks and Composites, Saxifrages and succulent plants which inhabit the rocks on the dry mountain-slopes at the present day, as of the Tulips and Irises, Umbelliferæ and Saltworts of the steppe-flora; and a great mistake would be made if, millions of years afterwards, it were reasoned from the lack of fossil remains of these plants that they could not have existed in our time. It would be just as wrong for us to argue from the absence of such plants in the strata of earlier periods that they had never existed in those times. The same thing applies to most fresh-water and marine Algæ, and to the numberless saprophytes which effect the destruction of dead animal and vegetable bodies above and under water, and thus maintain the eternal cycle of life as a whole. Of the first-mentioned the only fossil remains which can be recognized

are those of Diatoms, whose cell-wall is transformed into an imperishable siliceous frustule, together with those Floridæ which provide themselves like corals with a calcareous skeleton, and some tough Sea-wracks. It is, however, a very significant fact that the innumerable fossil Diatoms which come to us in so-called tripoli-powder and Diatom-earth, and the many calcareous Floridæ which come down to us as Nullipore banks are deceptively like those living at the present day, that these groups have remained unaltered for eons, and that no form has been discovered in any of the older strata which could be regarded as a link with another group. No fossil remains are known beyond doubt to exist of the numerous aquatic plants with delicate cell-walls which perish as rapidly as they develop, of the *Sphærella* species which give a red colour to rain-water and to the snow-field, of the microscopic Desmids, of the green filaments of *Spirogyra*, of the remarkable green tubes of *Vaucheria* pictured in plate I, &c. Some woody *Polyporus* species of Fungi have reached us, but in forms which look very like those at present growing on old tree-trunks. Some species of Moulds have been preserved in amber. I have before me a piece of amber in which insects are imbedded; from one of them spreads a web of mycelial threads which doubtless belonged to some mould-like Fungus such as to-day attacks various insects. The myceliums of various Fungi, also, are found penetrating the tissues of many of the fossil cryptogamic stems of the Coal Measures. This fact is very instructive, since it shows that in the tertiary period, and in much earlier periods also, the relation of saprophytic plants to the dead bodies of animals and plants were the same as they are to-day. All these results taken together prove that delicate Thallophytes whose cells do not become siliceous or calcareous, or which are not inclosed in resin, cannot be preserved in a fossil condition. But no one would conclude from this that the groups to which such delicate growths belong were not represented in earlier periods.

On comparing the past and present of the Vegetable Kingdom from these points of view, more especially with regard to the question whether existing groups stood side by side in earlier periods also, or whether, in the course of time, they have sprung from a single individual or from a few spontaneously-generated individuals, we are obliged to decide in favour of the former. The so-called "higher" plants are not derived from the so-called "lower"; the groups of higher and lower plants co-existed from the beginning side by side. But variations within the limits of each group have always taken place. New species, i.e. new groups of species, arose in consequence of the crossing of the species already in existence. Of these the species which were best suited to the climatic conditions of the time being survived. But the variation in the formation of new species never went so far as to do away with the characteristics of the group. We immediately recognize in the fossil Laurel-trees, Magnolias, Oaks, Palms, Grasses, Pines, Equisetums, Ferns, Lycopods, Floridæ, Diatoms, and Moulds the ancestors of the now existing species. This would be impossible if the group-characteristics had disappeared in the modifications which the species have undergone.

When I now attempt the task of stating in detail what has been furnished by

theoretical considerations, and of bringing forward the various groups which have from the beginning existed side by side, distinguishing them by the enumeration of their peculiar characteristics, I am not blind to the enormous difficulties of the undertaking. Although Palæontology, Morphology, and Physiology afford valuable results, they are not enough, and neither of the three sciences gives sufficient data for the complete solution of the problem. One of the greatest obstacles is the afore-said incompleteness of the geological record. From the existing remains we may indeed conclude on the whole that numerous groups stood side by side in the mesozoic and palæozoic periods, but the evidence of many groups which exist at the present day without transitional forms is wanting, and when we assume their existence we make use indeed of a justifiable hypothesis, but have no proof whatever. The danger, on the other hand, of establishing homologies from the similarity of an organ which is observed in groups of species now living has already been mentioned (see p. 609). Up to a certain point all organs which have similar work to perform agree with one another. This agreement is the more pronounced the greater the similarity of the conditions under which the organs have to do the work. Species of very different groups which live under water exhibit many characteristics in common; plants whose pollen-grains are transported by the wind show a great agreement in the structure and position of the parts of the flower. In the same way the form of flower-visiting insects necessitates a number of similar characteristics in the flowers visited. For example, we might instance the sweeping hairs on the style of the Proteaceæ and of the Composites, as well as certain developments which are met with in the flowers of Aroids, which are visited by small flies, and also in the Aristolochiaceæ. In spite of this consideration, however, the similarity in the structure and form of organs, both of those serving for propagation and for nourishment and growth, must obviously be kept to the forefront; similarity must always be an important factor in the limitation of groups.

As we have in the preceding chapter established the fact that each species is built up by protoplasm with a specific constitution, the question might be propounded whether each plant-group has not something in common in this respect. Many observations argue differently for this view. It has been repeatedly stated that the Moulds, Oscillatorieæ, Sea-wracks, Stoneworts, &c. give off a scent which, although it differs according to the species, is yet very similar upon the whole, and that one is justified in assuming a specific constitution of the protoplasm in each of these groups on this account. Moreover, the scent which the Mosses exhale is found in no other group of plants. The same is true of Ferns. The delicate fronds of the tropical Filmy Ferns exhale the same peculiar scent as the larger Ferns of our forests. The Coniferæ, Umbelliferæ, Labiateæ, Leguminosæ, and Cruciferæ exhibit similar conditions. Is it not also a striking phenomenon that the parasitic Fungus *Cronartium asclepiadeum* should settle on *Cynanchum Vincetoxicum*, as well as on *Gentiana asclepiadea*, i.e. upon two plants which the Botanist certainly places in different families, but which he regards as belonging to the same alliance? To these facts many others might be added, especially with regard to the choice of

vegetable food by animals. But our knowledge in this respect is so fragmentary and uncertain that for the present we cannot make use of these conditions in the limitations of the groups.

The capacity for sexual union is of the utmost importance in defining plant groups. Species which can unite sexually belong undoubtedly to the same group. Nothing can be urged against this principle, and if it could be universally applied, the division of the groups would be settled. But in this matter there are very many pros and cons. The converse of the proposition requires consideration. It will not do to say that all plants which cannot unite sexually belong to different groups. It has been shown that crossings can be successfully effected in Orchids which all Botanists regard as members of different genera, but, on the other hand, it is demonstrated that crossings between very similar species of the Umbellifer family lead to no fruit formation. No one, however, would conclude from this that these Umbellifers belonged to different groups. On reflecting in what a small number of flowering plants the fertilizing process has hitherto been observed, and remembering that the fertilization of many Thallophytes is still totally unknown, the hope of being able to utilize these conditions in limiting the groups becomes very much lessened.

In the review of the various groups of the vegetable kingdom which follows¹ no attempt is made to present the groups in the form of an ideal natural system. So far as the Thallophytes, Bryophytes, Pteridophytes, and Gymnosperms are concerned, there is a very general consensus of opinion amongst Botanists, and the serial arrangement here followed is in harmony with it. But as regards the Angiospermous flowering plants, and in particular the Dicotyledons, it is as yet too early in a book of this nature to embody all the most recent suggestions as to the affinities of the various families. Attention was drawn on p. 605 to the system of Alexander Braun, and it was pointed out that he was the first to try and break up the large and unsatisfactory class Monochlamydæ or Apetalæ, and to relegate its families in part to their true position. This attempt has been very fully carried out by Eichler (1883), and by Engler (1892); these two Botanists admitting only two classes of Dicotyledons (Choripetalæ or Archichlamydæ and Sympetalæ). But as yet many of their placings of individual families are but tentative, and we may well wait a few years for a system on these lines to settle down into more or less permanent form. An instance of too hasty rearrangement of a natural system to meet recently discovered facts may be quoted here. In 1891 Treub discovered that *Casuarina* possessed chalazogamic fertilization, and in 1892 Engler (following Treub) separated *Casuarina* from all other Angiosperms as the sole genus in a new class Chalazogamæ. Since then it has been found (see p. 413) that chalazogamic fertilization is much more general than was at first supposed, and that in the group Amentacæ it is widely spread, though by no means of universal occurrence. To break up the Amentacæ in the drastic manner involved, if the class Chalazogamæ be maintained, seems a most

¹ Cf. editorial note at commencement of this volume.

undesirable and unnatural thing to do; it will on the whole be best to abolish a special class of Chalazogams, and, if thought necessary, to rearrange the families which constitute the Amentaceæ, but not to sever them from one another. For the Angiosperms we shall in the main follow the arrangement of the well-known *Genera Plantarum* of Bentham and Hooker, though we reserve our freedom to deal with certain families as seems well to us.

The vegetable kingdom we divide first into four main divisions or *phyla*: (1) The Myxothallophyta, including the Myxomycetes only, a group standing apart from (2) the Thallophyta, which include the various classes of Algæ and Fungi. Then follows (3) the Archegoniata, forms possessing archegonia and fertilized by motile spermatozoids, and including the Liverworts and Mosses, and the series of the Ferns (Phyla (1) (2) and (3) constitute what are usually referred to as "Cryptogams"), and (4) the Phanerogamia or flowering plants, fertilized by means of pollen-tubes. They fall into two sub-phyla, Gymnosperms and Angiosperms, and the latter into two classes, Monocotyledons and Dicotyledons. Finally we have the 3 sub-classes of Dicotyledons—Monochlamydeæ, Monopetalæ, and Polypetalæ. Here, in outline, is the system:—

(1) MYXOTHALLOPHYTA, containing 1 class only.

(2) THALLOPHYTA, containing 5 classes.

- I. *Schizophyta*.
- II. *Dinoflagellata*.
- III. *Bacillariales*.
- IV. *Gamophyceæ*.
- V. *Fungi*.

(3) ARCHIGONIATÆ, containing 2 classes.

- I. *Bryophyta*.
- II. *Pteridophyta*.

(4) PHANEROGAMÆ, containing 2 sub-phyla.

A. GYMNOSPERMÆ.

B. ANGIOSPERMÆ, containing 2 classes.

- I. *Monocotyledones*.
- II. *Dicotyledones*, containing 3 sub-classes.
 - a. *Monochlamydeæ*.
 - b. *Monopetalæ*.
 - c. *Polypetalæ*.

Each class (or sub-class) is further divided into a number of cohorts or *alliances*, and each of these alliances into orders or *families*. The alliances will be taken one by one in the following pages, their main characters generally indicated, and the families which they comprise enumerated. It will not be possible within the limits of this book to deal with the several families in at all a comprehensive manner, though the endeavour will be made to point out structural and other characters of interest, and where certain genera or groups of genera have a special interest these will be alluded to. No attempt is made to observe any due sense of proportion in treating of the different alliances. Thus a small alliance containing but few members of especial interest will receive more detailed consideration than one vastly

larger, the numerous representatives of which are unrelieved in their monotony. This method, truly, is an unconventional one, but in view of the restrictions of space, perhaps better suited to our purpose than any other.

PHYLUM 1.—MYXOTHALLOPHYTA.

Organisms destitute of chlorophyll, whose vegetative state consists of a mass of naked protoplasm (plasmodium). Reproduction by spores, from which arise swarm-spores or myxamcæ, which unite again into plasmodia.

Alliance I.—Myxomycetes, Slime-Fungi.

For the most part saprophytic upon dead organic and especially vegetable substances; they occur chiefly on accumulations of the dead parts of plants—leaves,

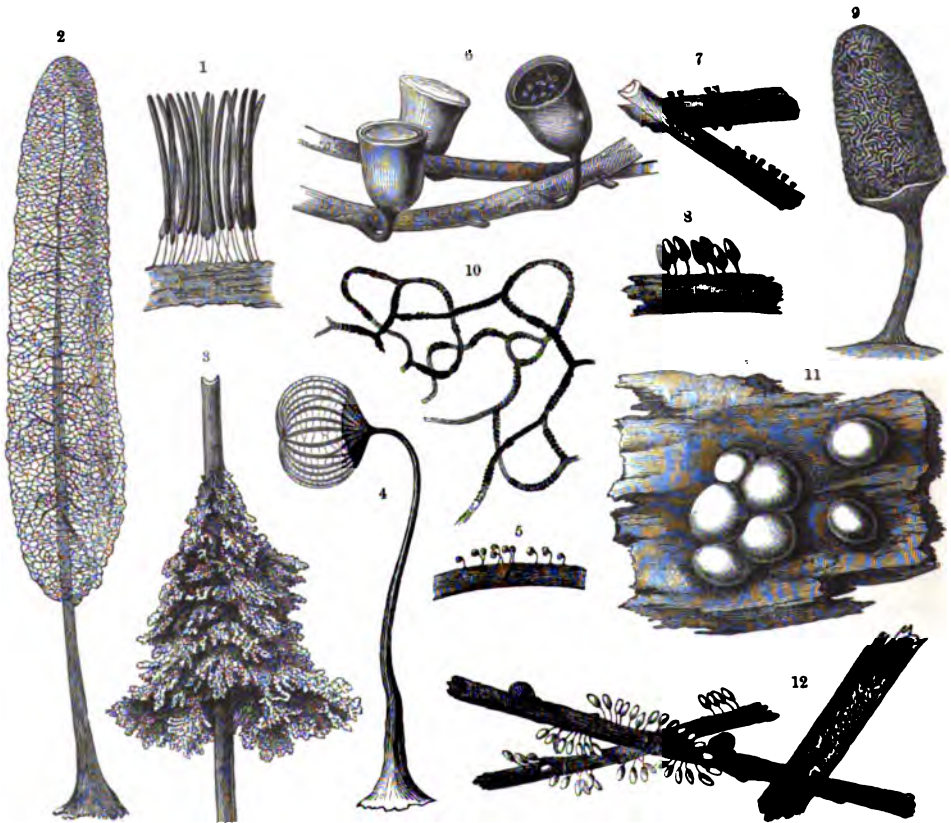


Fig. 367.—Myxomycetes.

¹ A group of sporangia of *Stemonitis fusca*. ² A single sporangium; $\times 6$. ³ Dendritic mass of sporangia of *Spumaria alba* on a Grass leaf. ⁴ Sporangium of *Dictydium cernuum*; $\times 25$. ⁵ A group of sporangia of the same. ⁶ and ⁷ Sporangia of *Craterium minutum*; $\times 25$. ⁸ Sporangium of *Arcyria punicea*. ⁹ A single sporangium; $\times 10$. ¹⁰ Part of the net-like capillitium of the same; $\times 100$. ¹¹ Fructification of *Lycogala epidendrum* on a piece of wood. ¹² *Leocarpus fragilis*; a plasmodium on the right; several sporangia on the left.

tan, rotting wood, and the like; they are rarely parasitic. Their life-history is as follows:—On the germination of the spores the membrane bursts, and a slimy, nucleated mass of protoplasm escapes, which either swims in water by means of a

single flagellum, or creeps about on a damp substratum; these motile bodies are the *myxamœbæ*. These amœbæ increase at the expense of absorbed nutriment, and undergo repeated division. Ultimately they fuse together into masses of naked protoplasm—the *plasmodium-stage*—which creep about until spore-formation sets in. The plasmodium is transformed into the reproductive stage, numerous sporangia arising all over its surface. This stage in different cases shows the most varied structure, as may be seen by reference to fig. 367. Either the whole plasmodium is transformed into a single sporangium, as in *Lycogala epidendrum* (fig. 367¹¹), or a number of sporangia arise. A portion of the protoplasm becomes hardened to form the wall of the sporangium, whilst the contents is resolved into a mass of dust-like spores. In addition there arises in the majority of forms a sort of internal skeleton, the *capillitium*, which may consist either of a number of elongated tubes with characteristic thickenings on their walls, or these tubes may be united together into a continuous network (fig. 367²). On the bursting of the sporangium the spores are scattered and carried away by currents of air. They germinate when they reach a moist substratum, and the life-cycle is passed through anew. Under unfavourable conditions a plasmodium may become encysted, forming a transitory resting-stage. If placed in water, the plasmodium escapes from the cyst, and continues its life-history even after a lapse of several months. The substance of the membrane, whether of the sporangial wall, spores, or capillitium, does not seem to consist of cellulose, but rather of a congealed protoplasm. We see, then, that the life-history of a Myxomycete is divided into a nutritive stage consisting of naked, membraneless, protoplasmic masses, and a sporangial, spore-producing stage. In respect of their nutritive stage the Myxomycetes very nearly resemble certain groups of the Protozoa, and on the strength of this resemblance they are regarded by many Botanists and Zoologists as belonging rather to the animal than to the vegetable kingdom. In their manner of reproduction they certainly show analogies to many of the Fungi however.

Plasmodiophora Brassicæ is a parasitic Myxomycete which attacks the roots of the Cabbage, causing the disease known as "Fingers and toes" (*cf.* p. 522).

Fossil Myxomycetes are not known. About 450 species have been distinguished.

PHYLUM 2.—THALLOPHYTA.

A large and very heterogeneous collection of plant-forms is included under this term. The word (Greek *θαλλός*, and *φυτόν*) literally means plants with undifferentiated shoots, and includes practically all plants standing below the Mosses and Liverworts in complexity of organization. It is impossible to characterize positively a group, or rather a collection of groups, which shows so wide a range of organization as we find among the Thallophytes. They are often characterized negatively as plants whose bodies show no distinction between axis and appendages (stem and leaves). To such a plant-body the name *thallus* is given. But though this definition holds good for the great majority of the Thallophytes, yet there are forms (*e.g.* *Bryopsis*,

the verticillate Siphonæ, *Draparnaldia*, many of the Brown Sea-weeds) which do show a distinction between axis and appendages, though the distinction is not usually so marked as that between the stem and leaves of a higher plant. Similarly, though for the most part possessing a relatively low organization, some Thallophytes (especially the higher Fungi and certain of the Brown Sea-weeds) show considerable differentiation of structure. The *Thallophyta* consist of many divergent and more or less sharply characterized groups. These include the Green Algæ (*Chlorophyceæ*, which includes the alliances Protococcoidæ, Siphonæ, Confervoidæ, Conjugatæ, and Charales), the Brown Sea-weeds (*Phæophyceæ*), the Red Sea-weeds (*Rhodophyceæ* or *Florideæ*), the Blue-green Algæ (*Cyanophyceæ* or *Schizophyceæ*), the Bacteria (*Schizomycetes*, here included with the last-named group in one class, the *Schizophyta*), the Diatoms (*Bacillariales*), and the Fungi. Some Botanists consider that the Myxomycetes (or *Mycetozoa*), and the Dinoflagellata (*Peridineæ*) are also plants. These last groups are almost certainly branches of the Protozoa; and though possessing certain plant-like characters (as indicated above), they show no near affinity with other plant groups. Whether they should be considered as plants or animals must therefore remain a matter of opinion.

The same may be said of certain other organisms regarded by zoologists as Flagellate Protozoa, but showing undoubted affinities with the lower forms of Green Algæ. There exists, in fact, an unbroken series of forms, connecting undoubted Protozoa, having mouths by which they eat solid food, with undoubted green plants depending entirely on soluble inorganic food. The dividing line between animals and plants is here obviously an artificial one, and is naturally drawn by different authorities at different points in the series.

The name Thallophyta, then, is given to all plant-forms below a certain grade of organization, and includes many separate and widely divergent lines of descent. The Thallophytes may be pictured as the shrubby growth around the base of the phylogenetic tree representing the plant kingdom. The lower part of the main trunk of the tree, that is to say, the line of descent by which the higher plants have originated, is probably represented by certain of the Green Algæ.

Class I.—SCHIZOPHYTA.

For the most part exceedingly small organisms, which propagate entirely by asexual methods. They consist of isolated cells, cell-filaments, surfaces, or masses. Though till recently regarded as without nuclei, these bodies have been found in a number of forms, and this view is being abandoned. They include both coloured and colourless forms; but the coloured forms never exhibit pure chlorophyll.

Alliance II.—Cyanophycæ, the Blue-green Algæ.

Families: *Chroococcaceæ*, *Nostocaceæ*.

Includes pigmented forms in which in addition to chlorophyll *phycocyanin* is present, giving the cells a bluish, violet, or reddish tint. They occur in water or in moist places, and their cells may be united together into aggregates of various kinds. The cell-walls are usually mucilaginous, so that the cells or filaments cling together in colonies, or they are inclosed in special sheaths. The simpler forms included under the *Chroococcaceæ* are unicellular; the products of their division may either remain united into colonies or become quite free from one another. The rest are filamentous, and are included under the *Nostocaceæ*, whose filaments can become segmented into small portions which move away by a peculiar motion not yet fully understood (*cf.* vol. i. p. 40). At times also certain cells become resting-spores and can endure climatic vicissitudes. They are widely dispersed over the globe, and are met with in cold glacier-streams and have been found living in hot springs at a temperature of even 85° C. Some 800 living species are distinguished.

Chroococcaceæ.—Includes the unicellular forms. *Glæocapsa* (vol. i., Plate I. n, o) forms little mucilaginous colonies, often found on the moist window-panes of hot-houses. *Merismopedia* forms films on stagnant water, and *Clathrocystis* like certain of the *Nostocaceæ* (alluded to below) arises in quantity in water. A form probably referable to this group (*Dermoglæa Limi*) developed in 1874 in such quantities off the Adriatic coasts as to seriously interfere with the fishing industry. A commission was appointed to investigate the matter, but in six weeks the *Dermoglæa* vanished as suddenly as it had appeared.

Nostocaceæ are, for the most part, filamentous, though in some forms the cells may become isolated. *Nostoc* itself is common, and takes the form of irregular gelatinous colonies, which contain numerous interwoven necklace-like filaments. In some districts, owing to its sudden appearance after rain, it has received the name of "Falling Stars". This explains the allusion in the following lines from Dryden's *Ædipus*:—

"The tapers of the gods,
The sun and moon, run down like waxen globes;
The shooting stars end all in *purple jellies*,
And chaos is at hand".

A species common in China, *N. edule*, is used as a thickening for soup, and an allied form, *Hormosiphon arcticus*, abounds in the Arctic regions upon floating ice. *Anabaena Flos-aquæ*, *Aphanizomenon Flos-aquæ*, &c., appear in fresh and brackish water—sometimes in enormous quantities, and to considerable depths. The *Trichodesmium Erythræum*—another of these "flowers of the sea"—referred to at vol. i. p. 389, belongs also to this group. Very little is really known about the life-histories of these interesting plants, which so frequently appear in great quantities at or near the surface of the water and then as mysteriously disappear. But now

that systematic observations are being made of the organisms which occur at the surface (e.g. at the Biological station on the Plöner See, Schleswig-Holstein) we may hope that these lacunæ in our knowledge may be filled up. Recent investigations (by Klebahn) upon several of these "flowers of the sea" (*Gloietrichia echinulata*, *Anabæna Flos-aquæ*, *Aphanizomenon Flos-aquæ*, *Trichodesmium*, &c.) seem to indicate that they possess special organs of flotation designated "gas-vacuoles". It would appear that these natant forms have in consequence a smaller specific gravity than the surrounding water, and if the surface be quite unruffled tend to float, whilst any disturbance, such as waves, &c., is sufficient to cause their distribution through the upper layers of the water. Whether these "flowers" pass another stage deep down in the water is not fully ascertained. Their spores, so far as they have been observed, do not seem to possess "gas-vacuoles", and sink to the bottom. The phenomenon here indicated is not unlike that occurring in the Protozoon *Arcella*, the protoplasm of which is able by secreting a bubble of gas to rise to the surface, and, by absorbing it, to cause the organism to sink. The *Oscillarias* consist of filaments of disc-like cells; they exhibit curious gliding movements, which have been already alluded to (cf. vol. i. p. 40). *Rivularia* is distinguished by the fact that its filaments are whip-like, ending in a fine point, whilst in *Scytonema* this distinction of base and apex is not found. They generally occur in more or less mucilaginous masses.

A number of the Schizophyceæ are associated with certain Fungi to form Lichens (cf. later, and vol. i. p. 244); and certain of them occur embedded in the tissues of other plants. Thus species of *Nostoc* are met with in certain Liverworts (*Anthoceros*) and in the roots of *Cycas*; and *Anabæna* in special cavities in the leaves of the Rhizocarp *Azolla*. It is not known what may be the exact physiological relations between these Blue-green Algæ and the plants they inhabit—whether they are parasitic or symbiotic.

Alliance III.—Schizomycetes, the Bacteria.

On the whole, in the matter of their structure and aggregation, present many characters in common with the Blue-green Algæ. They are, however, destitute of the characteristic pigment of that group, and pass their lives as parasites and saprophytes, obtaining their food from ready-formed organic matter. Nuclei have been distinguished in some few forms, and the cells are inclosed in a membrane which, though often mucilaginous, does not consist of cellulose. In size the cells reach very small dimensions, and may be regarded as the smallest of all plant-forms. A number of different forms are distinguished; the Cocci, consisting of minute round cells; short rod-like forms, the Bacteria; longer rod-like forms, the Bacilli; various spiral forms known as Spirillum, Vibrio, and Spirochæte; filamentous forms, Leptothrix and Crenothrix. A very common mode of occurrence of the various forms is in gelatinous masses, to which the name Zoogloea has been applied (cf. fig. 368²). Propagation takes place vegetatively by cell-division so long as the

conditions remain favourable for further growth. When the substratum is exhausted, &c., spores are formed which can remain for long periods—until, indeed, circumstances are again favourable for renewed development. These spores may arise either inside the bacterial cells (=endospores), the protoplasm contracting somewhat and forming a new wall around itself, or the cells may become transformed entirely into spores (=arthospores), the wall becoming specially thickened. In no case is there any sexual process. Whilst many Bacteria are only known under certain forms and are regarded as species of the genera *Micrococcus*, *Bacterium*, *Bacillus*, *Spirillum*, &c., others are known which, in the course of their development, pass through several such forms, and are termed pleomorphic. That all Bacteria are thus pleomorphic seems improbable, though the discovery that pleomorphism existed at one time led to the wildest generalizations. Large numbers of Bacteria display an active movement which, though formerly attributed to various contractions of their bodies, are now known to be due to cilia. These cilia may be borne in tufts of 5 or 6 at the two ends of the organism, as in *Spirillum Undula*, or they may be solitary at one extremity, as in the Cholera Bacterium (*Spirochæte cholerae asiaticæ*), or they may be scattered over the surface of the organism, as in the Hay-bacillus, *Bacillus subtilis*. It is due to the extreme fineness of these cilia that they were not recognized long ago.

Though the forms under which Bacteria occur are relatively few, their mode of life and special activity is exceedingly varied. The interest attaching to Bacteria rests largely on their effects on the substratum from which they draw their food. Taking, first, the saprophytes. These split up their substratum into simple substances. In some cases there is a complete oxidation, with production of carbon dioxide and water; in others this is only partial, as in some of the cases of fermentation, e.g. when alcohol is oxidized into acetic acid by the activity of the vinegar organisms *Bacillus* and *Micrococcus aceti* (cf. figs. 368³ and 368⁴). Or there may be a decomposition unaccompanied by simple oxidation, as in many cases of fermentation, e.g. as when sugar is split into alcohol and carbon dioxide. Often these operations are accompanied by the development of a foul-smelling gas, when we speak of putrefaction. The number of saprophytic Bacteria which excite characteristic splittings in their substrata is considerable. In addition to those already quoted, we may mention *Bacillus Amylobacter*, the organism of butyric acid fermentation; *Bacillus lacticus*, which causes milk to become sour; *Leuconostoc mesenterioides*, which has the power of converting large quantities of sugar into a gelatinous mass in a very short space of time. Again, in a number of forms the production of a special colouring matter is associated with the activity of the organisms, as is the case with *Micrococcus prodigiosus* (cf. fig. 368¹), the "blood-portent" which makes its appearance on various starchy food-stuffs, and *Beggiatoa roseo-persicina*, found on decaying vegetable matter in water, and known as "peach-mud". Many Bacteria are parasitic in the bodies of animals, and some among them are harmless. This is the case with *Sarcina ventriculi* (fig. 368¹⁰), known only in the human alimentary canal in the form of packets of cells. Harm-

less also are a number of Bacteria found on the mucous membrane of the mouth. On the other hand, many are associated with definite diseases. *Spirochæte Obermeieri* (fig. 368⁹) is found in the blood in great quantities during relapsing fever; *Bacillus anthracis* (figs. 368⁷ and 368⁸) causes anthrax in cattle, &c.; and a great many other diseases—diphtheria, cholera (figs. 368⁵ and 368⁶), tuberculosis, leprosy, &c.—are associated with the activity of specific bacterial organisms. Nor must we omit to mention the numerous forms which occur in the soil, some of which are concerned in the process of nitrification, *i.e.* which oxidize ammonia into nitric acid, thus rendering this source of nitrogen available to higher plants, whilst others

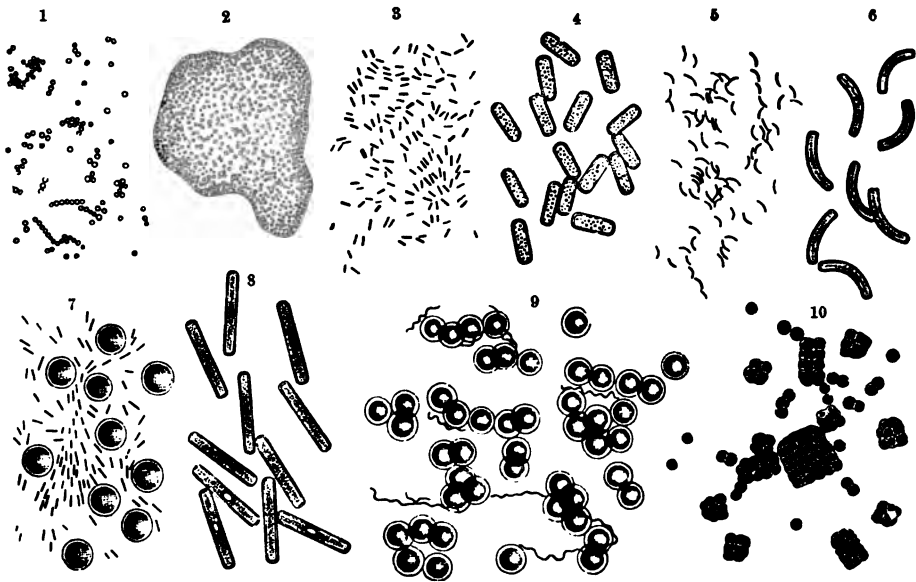


Fig. 368.—Bacteria.

¹ The "blood-portent," *Micrococcus prodigiosus*. ² Zoogloea-form of same. ³ *Bacterium aceti*. ⁴ The same more highly magnified. ⁵ *Spirochæte cholera asiatica*. ⁶ The same more highly magnified. ⁷ *Bacillus anthracis* and red blood-corpuscles. ⁸ The same more highly magnified. ⁹ *Spirochæte Obermeieri* and red blood-corpuscles. ¹⁰ *Sarcina ventriculi*.
1, 2, 3, 5, 7, 9 $\times 300$; 10 $\times 800$; 4, 6, 8 $\times 2000$.

actually fix free nitrogen, as is the case with the organism occurring in the root-tubercles of many leguminous plants (*cf.* p. 521). There is no doubt this organism (*Rhizobium*, as it has been called) can store up free nitrogen, and that leguminous plants, when associated with it, obtain nitrogen not to be accounted for as combined nitrogen obtained from the soil. Curious also is the activity of the sulphur and iron Bacteria. The former (*e.g.* *Beggiatoa alba*) have the power of reducing the sulphates contained in the waters which they inhabit and of storing up sulphur-grains in their protoplasm; whilst the latter (*e.g.* *Crenothrix Kühniana*), not uncommon in water-pipes, where they often develop in enormous quantities, store up iron in the gelatinous sheaths of their filaments.

That Bacteria existed in former times, and were then, as now, the agents of decomposition, seems probable in view of the condition revealed by residues of dead

plants in the coal measures. It is thought that *Bacillus Amylobacter* has been identified in a silicified state.

Of living Bacteria a very large number have been distinguished.

Class II.—DINOFLAGELLATA, Peridinea.

Alliance IV.

This compact group of unicellular organisms is, as has been said above, a branch of the Flagellate Protozoa. They have therefore no very near affinities with other plant groups, though the nutrition of many is thoroughly plant-like. They would come nearest to the motile (Flagellate) forms of Protococcoideæ (see p. 628).

The great characteristic of the group is the possession of two flagella, one directed longitudinally and attached to the anterior end of the body, the other transversely directed and often situated in a circular transverse groove. There is sometimes also a longitudinal furrow. It is this transverse flagellum which is specially concerned in movement.

There is often a cell membrane of cellulose, and the cell possesses green or brownish chromatophores containing chlorophyll and a single large nucleus.

Reproduction is effected by binary fission, usually during a resting stage of the cell.

Most of the forms are marine, and some are the cause of sea-phosphorescence.

The group is divided into two sections—the *Adinida* without, and the *Dinifera* with a transverse furrow.

Ceratium and *Peridinium* are two well-known genera.

Class III.—BACILLARIALES.

Alliance V.

Family: *Diatomaceæ*, Diatoms.

These are a large group of unicellular plants which grow both in fresh and salt water and upon moist soil. As a rule they occur together in large numbers. The protoplasm is coloured brown by a brown pigment, *diatomin*, which masks the chlorophyll which is also present. The colouring matter is restricted to special chromatophores, which may be few or numerous. The cell-wall is incrustated with silica, and is a very characteristic feature of the Diatom. The wall consists of two halves or valves (*frustules*) which fit into one another like the lid on to a pill-box. These valves are smooth or variously sculptured, dotted, ribbed, &c., and enjoy a wide popularity as microscopic objects on account of the beauty and delicacy of their tracery. Some idea of the variety and form of Diatom-cells may be obtained from the accompanying figure 369. In the colonial forms the cells are attached to the substratum directly (fig. 369¹) or by means of branching filaments (fig. 369¹⁴). Others are attached to one another in zigzag chains or continuous ribbons (figs. 369¹⁵ and 369¹⁶). Others, again, are embedded in mucilage. Many of the forms

exhibit a curious creeping movement, which is explained as being due to an external sheath or to filaments of protoplasm; the median line (or "raphe") shown by certain forms (e.g. *Navicula*, fig. 369⁴) is interpreted as a narrow slit at which this external protoplasm is extruded. Diatoms propagate by continuous longitudinal division; the valves are slightly separated, and division takes place parallel to the faces of the valves. Each daughter-cell thus possesses one of the valves of the mother-cell, and they complete their integument by secreting another on the side away from it. The new valve is always slightly smaller than the other one and

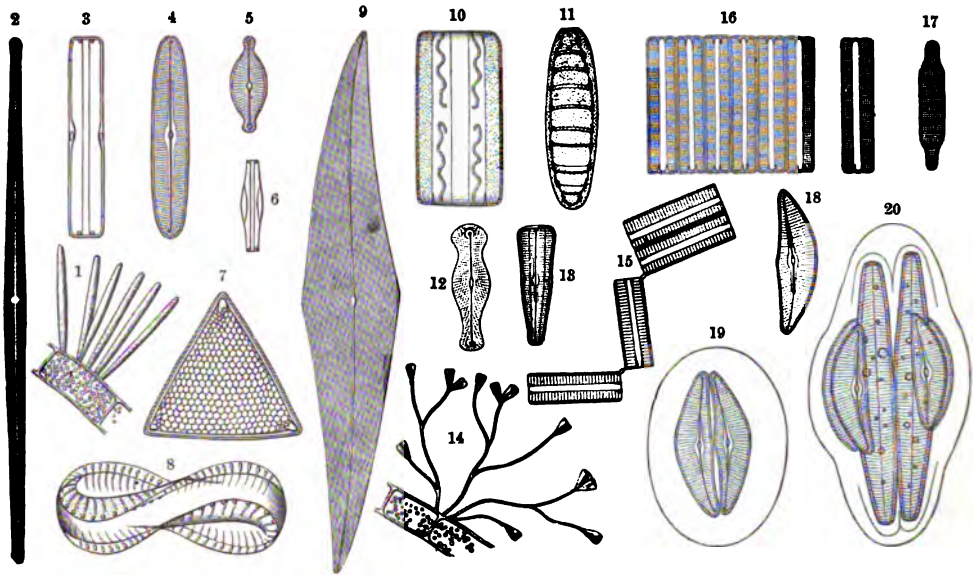


Fig. 369.—Diatoma.

¹ Several individuals of *Synedra Ulna* attached to a cell of an aquatic plant. ² A single individual of *Synedra Ulna* more highly magnified. ³ and ⁴ *Navicula Liber*, seen from the side and from in front. ⁵ and ⁶ Similar views of *Navicula tumida*. ⁷ *Triceratium Favus*. ⁸ *Campylodiscus spiralis*. ⁹ *Pleurosigma angulatum*. ¹⁰ and ¹¹ *Grammatophora serpentina*. ¹² and ¹³ Two views of *Gomphonema capitatum*. ¹⁴ *Gomphonema capitatum* on branched stalks which are attached to some algal filament. ¹⁵ *Diatom vulgare*; the cells hang together into a zigzag band. ¹⁶ and ¹⁷ *Fragillaria virescens*, showing an individual from two aspects and a row of six joined together into a ribbon. ¹⁸ *Cocconema Cistula*. ¹⁹ Two individuals of *Cocconema Cistula* inclosed in a mucilaginous envelope preliminary to auxospore-formation. ²⁰ The two auxospores have elongated, and the old cases are seen to right and left; there is no conjugation in this instance. All highly magnified.

fits under its rim, so that the Diatoms arising in this way become smaller and smaller till a certain minimum is reached. When this diminution has gone on for a certain period an enlargement is attained by the formation of what are termed *auxospores*. The contents of the cell gather themselves together, they become free from the valves, enlarge, and then put on new valves. In other cases an actual conjugation takes place, two individuals uniting into an auxospore; or each may divide into two daughter-cells, which fuse in pairs, forming two auxospores. Fig. 369¹⁹ shows two cells of *Cocconema Cistula* embedded in mucilage previous to auxospore-formation; in fig. 369²⁰ each cell has escaped from its valves, and has doubled its original length. In this instance, however, there is no accompanying conjugation.

Diatoms are very widely distributed over the globe, and occur in quantities in

the surface layers of the sea; some 30 species have been found amongst the inorganic dust of the snow-field. There are some 2000 species of living forms.

Considerable deposits of Diatoms occur in various parts of the world; of these the most remarkable is that of Richmond, Virginia, U.S.A. It is said to extend for many miles and to be 40 ft. deep. They are found in secondary, tertiary, and more recent rocks. Siliceous marl consists entirely of the tests of Diatoms. A block of such a Diatom-deposit some two cubic feet in bulk from a fresh-water lake in Australia is exhibited in the Botanical Department of the British Museum; the number of Diatoms contained in it (there are 21 different species) is estimated as exceeding 12 billions (12×10^{12}).

Class IV.—GAMOPHYCEÆ.

Sub-class I.—CHLOROPHYCEÆ, the Green Algæ.

There can hardly be a more fascinating group of plants than this, whether to the strictly scientific botanist or to the more catholic lover of nature. In the first place, the Green Algæ are among the most widely diffused of plant-forms. They grow practically in every place where enough moisture, together with light and air, are to be had. Between tide-marks on almost every coast, floating on the surface of the deep sea, covering damp earth, walls, palings, and tree trunks, sticking to the surface of leaves in the moist atmosphere of tropical forests and jungles, and inhabiting almost every river, brook, pond, ditch, or casual pool of rain-water in all quarters of the globe, are members of this ubiquitous group to be found. Nor are they wanting from more extraordinary situations. In Switzerland, Norway, and other countries where snow is more or less permanent, the bright red patches on its surface, known as "red snow", are formed by the microscopic Alga (*Sphærella nivalis*) shown in Plate I. of the first volume. Other forms, not so far removed from *Sphærella*, live in the intercellular spaces of higher plants, such as the Ivy-leaved Duckweed (*Lemna trisulca*), the Moneywort (*Lysimachia nummularia*), and others. Yet other Algæ are found inhabiting the jelly of certain fresh-water sponges in the East Indies, where they seem to live in a regular symbiosis with their hosts. But perhaps the most curious dwelling-places of all are the hollow hairs of the Three-toed Sloth (*Bradypus tridactylus*), which are inhabited by an Alga called *Trichophilus*.

In the second place, many of the Green Algæ (and among these some of the very commonest) are the most beautiful forms of life imaginable, and the main features of their structure can be made out with quite low powers of the microscope.

But perhaps the greatest claim on our interest is made by the fact that we must look among the Green Algæ not only for indications of the origin of all plant life, and of the forms from which the whole of the higher plant world arose, but also for hints towards the solution of some of the most difficult and fundamental problems with which Biologists are occupied, questions as to the real nature and origin of sexual reproduction, as to the distinction between gametes and asexual reproduc-

tive cells, as to the physiological conditions which determine their formation, and finally, questions as to the division of labour in the protoplast itself, the function of the nucleus and its relation to the protoplasm, and how far the latter can be resolved into separate, but mutually co-operative parts.

The framework of our knowledge on the former group of questions has been, and is being, built up largely from a study of the Green Algæ; of the latter—and even more fundamental—we know, as yet, very little, but the same group of plants is already beginning to yield important results, and we have every reason to expect an even richer harvest in the immediate future.

We shall now proceed to a brief review of the groups into which the Chlorophyceæ may be divided, mention being made of the more interesting forms in each group.

The sub-class Chlorophyceæ may be defined as follows:—Thallus of very various form, one- or many-celled, coloured green by chlorophyll which is contained in chromatophores of very various shape: the green colour rarely masked by other pigments. Reproduction by motile *zoospores*, and by *gametes*, which either resemble small zoospores, and are equal in size (*isoplanogametes*), or are differentiated into two categories; first, relatively small, active male gametes—called *spermatozoids* when they are very highly differentiated—and secondly, relatively large, passive female gametes—known as *eggs* or *oospheres* when they are quite passive. The cell produced by the fusion of the bodies of two gametes is called the *zygote*, and gives rise to a new plant either mediately or immediately. When the gametes are sexually differentiated, the zygote (now called a *fertilized egg* or *oospore*) is produced only by the fusion of a male with a female gamete.

Other reproductive cells are known as *aplanospores* and *akinetes*. *Aplanospores* are formed by the protoplasm of a cell of the thallus rounding itself off and putting on a *new cell-wall*, or dividing into several parts, each of which acquires a separate cell-wall. *Akinetes* are simply single cells of the thallus, whose *original walls* thicken directly, the cells becoming separated from the rest of the thallus. These two categories of reproductive cells germinate at once to form new plants. The Chlorophyceæ comprehend the following alliances:—Protococcoidæ, Siphonæ, Confervoidæ, Conjugatæ, and Charales.

Alliance VI.—Protococcoidæ.

Families: *Chlamydomonadæ*, *Volvoceæ*, *Pleurococcaceæ*, *Endosphæraceæ*,
Hydrodictyaceæ.

Unicellular forms, actively swimming, floating, or fixed in habit, living either singly or united into colonies.

Family *Chlamydomonadæ*. This family consists of minute green (sometimes red) organisms which spend the greater part of their life actively swimming about in water. Several species of the genus *Chlamydomonas* are very common in stagnant water. Each *Chlamydomonas*-cell consists of a roundish mass of proto-

plasm covered by a delicate cell-wall of cellulose. At first sight the whole body appears green, but on careful examination it will be seen that the green colouring-matter is really confined to a layer on the surface of the body. This chlorophyll-layer or *chromatophore* is specially thickened at one end (the posterior end) of the body, and a small, clear, spherical body (the *pyrenoid*) is often to be seen inclosed in this thickened portion. Round the sides of the body the chromatophore is thinner, and towards the anterior end it stops, leaving a small area of colourless protoplasm to occupy the front extremity of the organism. This is in connection with another small mass of colourless protoplasm which occupies the hollow of the cup-shaped chromatophore.

A minute red speck is visible at one side of the body, situated sometimes on the surface, sometimes at the limit between the chromatophore and the central colourless protoplasm. The rotation of the *Chlamydomonas* about its antero-posterior axis, which accompanies the jerky, forward movement (*cf.* vol. i. p. 29) can be well traced by the aid of this eye-spot, which can be seen to be carried round and round as the organism turns on its axis. The means by which the *Chlamydomonas* moves are not at first sight apparent. But when the cell has come to rest, and especially if it has been killed and its protoplasm fixed with a dilute solution of iodine, a pair of very delicate protoplasmic filaments, called *flagella*, can often be seen projecting from the colourless anterior spot of protoplasm. It is by the continual lashing of these flagella that the *Chlamydomonas* is pulled through the water. The iodine will also bring into view a small spherical *nucleus*, stained dark brown, situated in the colourless central protoplasm, and will stain the neighbourhood of the pyrenoid a dark blue. This last phenomenon is due to the formation of starch by the protoplasm round the pyrenoid. The exact part played by the pyrenoid is very obscure, but there can be no doubt that it influences in some way the formation or deposition of starch by the protoplasm.

The movements of *Chlamydomonas* are often in direct relation to light, the organisms moving towards a source of light of moderate intensity. Thus if a glass vessel filled with water containing *Chlamydomonas* be placed in a sunny window, there will be a general movement of the swarming cells to the sunny side of the vessel, causing the water to become much greener on that side. There is some evidence that it is the eye-spot which enables the organism to perceive the direction from which light is proceeding. Nearly all the motile Protococcoideæ, as well as zoospores and gametes which are sensitive to light, possess an eye-spot, and it has been thought that the eye-spot-pigment (a substance called *hæmatochrome*) may act in the same way as the visual purple in the retina of the eye.

If specimens of *Chlamydomonas* be kept for a day or two in water, some of them will often be found to have divided to form daughter individuals, which still remain inclosed within the cellulose membrane of the mother. This division is preceded by the drawing in of the flagella. The protoplasm of the body then withdraws itself from the wall, and divides transversely to form two roundish masses. Each of the latter may either at once put on a cell-wall and develop flagella, or it may divide

again, so that four daughter individuals instead of two are formed. Eventually the daughters escape from the membrane of the mother, leaving it quite empty.

The process of reproduction by simple division of all the protoplasm of an individual's body into parts, each of which forms the body of a daughter individual, is an example of almost the simplest type of reproduction known. It is true that in the lower Protozoa, which have no rigid cellulose membrane, we find an even simpler type. Since the entire organism consists of protoplasm, there is nothing left of the parent individual after division has taken place. The body of the parent simply *becomes* the body of the offspring. In the type of *Chlamydomonas* we have the dead cellulose membrane representing all that is left of the body of the parent. In many of the higher Algæ, and in all plants above the level of Thallophytes, only a *part* of the protoplasm of the plant-body is used in the formation of the reproductive cells. The rest must then eventually die. But in these lower forms, where all the protoplasm of the body is used in the production of new individuals, death, as a necessary event, can hardly be said to occur.

Gametes are formed in *Chlamydomonas* in exactly the same way as daughter individuals. They are, however, smaller and have no cell-wall. In one species at least the gametes are of two sizes. Of the smaller (*microgametes*) eight are produced from a parent individual, while only two of the larger size (*megagametes*) are formed from the parent cell. In the process of conjugation a microgamete and megagamete come into contact at their anterior colourless ends, the flagella are drawn in, and a thick cellulose membrane is secreted round the bodies of both. The protoplasm of the microgamete then passes over into the space inclosed by the part of the membrane belonging to the megagamete, and completely fuses with the protoplasm of the latter. A wall is then formed, cutting off the empty shell of the microgamete. The contents of the zygote eventually divides to form two or four new individuals which escape from its membrane. In the conjugation of most species where there is no distinction in size between the gametes, a cell-wall is only acquired *after* the foundation of the zygote. This is the regular course of events in the conjugation of the motile gametes of Green Algæ.

The genus *Sphærella* resembles *Chlamydomonas* in the fundamental points of its structure. The main distinction is the existence of a considerable space separating the membrane from the main body of the protoplasm of *Sphærella*. This space is bridged by fine strands of protoplasm, which radiate from the central mass and end in fine branches under the membrane. The anterior colourless protoplasm is drawn out into a beak, and to the extremity of this the two flagella are attached. The flagella often pass through two very delicate cellulose tubes, which in the common species, *S. pluvialis*, diverge from the extremity of the beak, and end on either side at the membrane. In another species (*S. Bütschlii*) the beak runs right up to the membrane, and the flagella-tubes, which are short and slightly curved, lie on the outer surface of the membrane.

Sphærella pluvialis is a very well-known microscopic object, being extremely common in pools of rain-water. Its protoplasm often contains a good deal of the red

pigment hæmatochrome, which may almost completely mask its green colour. It was from this circumstance that it received its name of *Hæmatococcus pluvialis*. Hæmatochrome is even more constantly present in *Sphærella nivalis*, the "red snow", whose appearance and life-history have already been described (vol. i. p. 39). *S. Bütschlii* has its hæmatochrome concentrated in an eye-spot like that of *Chlamydomonas*.

The *Volvoceæ* differ from the *Chlamydomonadeæ* in consisting of motile colonies of cells, the members of each colony being united in a common investment. The bodies of the individuals composing the colony are also joined in some genera by protoplasmic processes. The body of each individual is identical, in the fundamental points of its structure, with that of a *Chlamydomonas* or of a *Sphærella*. The *Volvoceæ* present us with an interesting series of forms, showing a gradually increasing sexual differentiation of gametes, and, in the higher forms, an interesting subordination of the individual to the colony as a whole.

Gonium is a form in which the colony consists of (usually) sixteen *Chlamydomonas*-like cells arranged in a flat plate, which swims in a line at right angles to its surface, the flagella of the central cells of the disc projecting forwards, those of the peripheral cells obliquely outwards and forwards. All the cells are inclosed in a general mucilaginous envelope, and are joined to one another by protoplasmic processes.

Reproduction is effected by the division of the constituent cells of the colony in two planes at right angles to one another and to the plane of the colony, so that each mother colony produces sixteen daughter colonies, whose discs of cells all lie in the same plane. Meanwhile, the mother cells are separated from one another by the gradual liquefaction of the general mucilaginous envelope, and thus the daughter colonies become independent.

Formation of isogametes also takes place, but is not thoroughly understood.

Stephanosphæra is a very beautiful form, occurring especially in pools of rain-water collected in rock hollows in hilly districts. It is often found in company with *Sphærella pluvialis*. The colony consists of a ring of (usually) eight *Sphærella*-like cells arranged in the equatorial plane of a spherical or ovoid cellulose membrane.

When reproduction is about to occur, the constituent cells draw in the protoplasmic processes by which they are attached to the general membrane; each secretes a membrane of its own, and then its protoplasm divides in two planes to form eight (sometimes seven) daughter-cells. When these have acquired flagella they begin to swarm, and eventually escape by bursting the membrane of the mother colony.

Gametes are formed in the same way, but usually by more divisions, as many as thirty-two being sometimes produced from a single cell. In most cases all the cells of a colony divide at once to form gametes, but this is not invariably the case. Each bundle of gametes produced from a single cell breaks up, and all the gametes begin to swarm within the colony. The gametes are spindle-shaped, each with two flagella and an eye-spot. They conjugate in pairs, usually inside the general membrane, but conjugation never takes place between two gametes derived from the

same mother cell. The actual process of pairing has been fully described, and it may be taken as a type of the course of events, as it has been observed in all Algæ with isoplanogametes whose pairing has been fully investigated. Out of the crowd of gametes swarming in all directions, two approach and stroke each other with their flagella; in some cases the two separate and both become again lost in the crowd, but, when pairing is going to take place, they become firmly fixed together by their colourless anterior ends. The long axes of their bodies may then lie in one straight line, or may diverge at a wide angle. A rotation of each of the pairing gametes about its fixed anterior end now always occurs, the bodies becoming gradually approximated, so that their long axes come to lie nearly parallel. Fusion of the protoplasm follows, beginning at the already joined anterior ends, and progressing rapidly backwards till a single mass of protoplasm is formed. The four flagella still move actively, and the *Zygozoospore*, as this active type of zygote is often called, escapes from the general membrane of the mother colony, becomes spherical by shortening of its long axis, loses its flagella, and puts on a cell-wall. The protoplasm soon loses its green colour, becoming reddish, and the zygote enters on a resting period. Eventually its protoplasm divides, producing zoospores, each of which gives rise to a new colony.

The division of the cells of a colony to form zoospores or gametes begins in the evening, and is finished soon after sunrise. In dull weather, however, its completion is delayed far into the day. This dependence of the formation of zoospores and gametes upon the influence of light, if not invariable, is found very widely among the Green Algæ.

Pandorina is a fairly common form in ponds, &c. The colony consists of sixteen wedge-shaped cells arranged in a sphere, and covered by a general investment, which is of considerable density at its external surface. The apex of each wedge is directed towards the centre of the sphere, and there is little space left between the adjacent cells. The formation of daughter-colonies is similar to that obtaining in *Gonium* and *Stephanosphaera*. The young colonies escape by liquefaction of the investing membrane. Colonies of gametes are formed in the same way, but often consist of eight instead of sixteen cells, and the acquirement of flagella and liquefaction of the mother membrane takes place more slowly. Eventually the membrane of each gamete-colony also becomes liquefied, and most of the gametes swarm out into the water. A great number of mother colonies of different sizes simultaneously take part in this production of gametes, so that the water becomes filled with masses of swarming gametes of very variable dimensions. No distinct size-categories are, however, to be distinguished. Conjugation now takes place between pairs of gametes either of the same or of different sizes; with this exception, that the largest gametes do not fuse with one another. They are relatively inactive, sometimes, indeed, remaining fixed in their colonies, and are sought out and paired with by the smaller and more active individuals. Here, then, we have a most interesting stage in the evolution of sex. The largest, relatively passive, gametes may fairly be called female, while the different sizes of smaller

gametes, though not sexually differentiated *inter se*, since conjugation is apparently possible between any two, whatever their relative size, may perhaps be considered as male in relation to the largest.

It is probable that fully-differentiated male and female gametes arose from forms such as we find in *Pandorina*, by the suppression of the intermediate sizes, the smaller and more active gametes taking on the function of actively seeking out the larger passive individuals, which on their side contribute practically the whole of the stock of food required by the zygote in germination. In correspondence with this we find the chromatophore (chlorophyll-corpuscle), which may be considered as the specially food-producing organ of the algal cell, much reduced and eventually functionless or absent altogether in the more highly differentiated male gametes (*spermatozoids*).

Eudorina has a colony of sixteen or thirty-two almost spherical cells considerably separated from one another, and inclosed in a general investment like that of *Pandorina*. In the production of daughter-colonies *Eudorina* resembles the lower forms of the volvocine series, but in the sexual differentiation of the gametes there is a decided advance upon that obtaining in *Pandorina*. The perfectly passive female gametes (oospheres) hardly differ from the ordinary cells of a vegetative colony, while the active male gametes (spermatozoids) are formed in bundles of sixty-four by successive divisions of similar cells. Here, then, we find the marked difference in size between the two categories of gametes brought about, as it very often is among the Algæ (and, indeed, among many other plants and animals), by a marked difference in the number of divisions occurring in their respective mother-cells. The present case in which strictly comparable cells on the one hand directly give rise to eggs, and on the other divide to form sixty-four spermatozoids each, is rather extreme, but we have already met with a similar case in a species of *Chlamydomonas*.

Each spermatozoid of *Eudorina* is club-shaped, with a colourless pointed anterior end bearing two flagella and possessing an eye-spot, and a yellowish thick posterior extremity representing the (reduced) chlorophyllous portion of the typical volvocine cell. The spermatozoid bundle (male colony) escapes from its mother-cell-membrane, and swarms as a whole towards a female colony. On reaching the latter the spermatozoids get their flagella, become entangled in the thick mucilage, and rapidly separating from one another, worm their way into the female colony. Some succeed in fusing with the individual female gametes, and each zygote thus formed will eventually give rise to a new *Eudorina* colony.

A form recently discovered almost at the same time in three different States of North America, and known as *Pleodorina*, shows an important difference from the types we have hitherto been considering. Each spherical colony consists of about 128 cells, but not all of these are capable of producing daughter-colonies. This power is confined to those cells which occupy the posterior half or two-thirds of the sphere (it should be explained that the colony moves forward in relation to a definite axis). The smaller anteriorly-placed cells are thus purely vegetative in

function, and necessarily die after the reproductive cells have given rise to daughter-colonies. This is the first time we have met with such natural death among the Algæ, and it is very clearly seen to be connected with the separation of the assimilative and reproductive functions. The formation of gametes in *Pleodorina* has unfortunately not yet been observed.

The remarkable and beautiful organism called *Volvox* has been known for more than two centuries, and has long been among the most favourite of microscopic objects. The purely scientific interest which it has aroused has been as great as the æsthetic admiration which it has excited. Long and animated controversies have raged on the question as to whether it was to be regarded as an animal or a plant, as an individual or as a colony of individuals. And although these questions have now lost much of their actuality through the gradual recognition by naturalists that we have absolutely no criteria by which they can be settled, there have arisen problems which promise quite as much interest and excitement for the future.

Volvox is much larger than the forms hitherto described. The colony is spherical, and possesses a single layer of cells on its surface. In *V. Globator* the sphere may be over a millimetre in diameter, but more usually its diameter is only some three-quarters of a millimetre. A particularly large specimen may possess as many as 22,000 cells (10,000 is a more usual number). Many of the cells, however, as in *Pleodorina*, are simply vegetative, and take no part in the reproduction of the colony. Usually, in fact, only a very small minority of the cells are reproductive.

The two species of *Volvox* differ from each other in a great number of points, but we have only space for a very brief description of some of the most interesting.

The cells of *Volvox Globator* are all united together by very stout processes. Each cell, which is inclosed in a separate cell-wall, possesses all the ordinary features of the *Chlamydomonas* type.

Daughter-colonies are developed from special cells, usually eight in number, called *parthenogonidia*. They are always formed in the posterior part of the mother-colony, early becoming larger than the ordinary vegetative cells. Each divides repeatedly, and forms a hollow sphere of closely-packed cells, which, after the last division, mostly acquire the characters of the adult vegetative cells, the remainder gradually increasing in size to form the reproductive cells. The young colonies then escape from the mother, apparently by pushing themselves against and making rents in its posterior wall. Subsequently the cell-membranes swell a good deal, separating the cell-bodies from one another, and the colony attains its adult size.

In other cases gametes may be formed in a young colony. About five cells (*androgonidia*), strongly resembling the *parthenogonidia*, divide to form discs or hollow spheres of a hundred or more spermatozooids. The spermatozooids resemble in a general way those of *Eudorina*, but are peculiar in having the pair of flagella inserted laterally at the base of the colourless beak and near the eye-spot. In the

same colonies, but a little later than the androgonidia, about thirty much larger spherical cells, the oospheres, are developed, and these are duly fertilized, but by spermatozooids derived from another colony. The zygote has a sculptured exine. Parthenogonidia are not found in those colonies which produce gametes.

Volvox aureus (= *V. minor*), the commoner form, is usually much smaller than *V. Globator*, and has rounded cells more widely separated and connected by very delicate processes. But perhaps its most striking characteristic is the very great variability in the number and distribution of the reproductive cells. The parthenogonidia, which vary in number from one to sixteen, may either occur alone or in one colony with androgonidia or oospheres, or both. Most of the sexual colonies are dicecious, though this is not always the case. The colonies containing androgonidia unaccompanied by other reproductive cells often develop very numerous (up to 1100) spermatozoid bundles, the androgonidia forming one-third of all the cells of the colony. The spermatozooids differ from those of *V. Globator* by their larger size, by their terminal flagella at the end of a shorter beak, and by the possession of a well-developed leaf-green chromatophore. We must, therefore, consider *V. aureus* as not so highly developed, in some respects at least, as *V. Globator*.

A *Volvox*-colony always swims in the direction of a given axis passing through its body, and at the same time rotates to the right or left about an axis which is inclined obliquely to the antero-posterior axis. The eye-spots of the vegetative cells are much better developed in the anterior half of the colony, and are always situated on the side of the cell nearest the anterior pole. These facts tend to support the view of the function of eye-spots in general suggested above.

Volvox stands at the head of the series of colonial (cœnobe-forming) organisms which we have been tracing, a series diverging from a *Chlamydomonas*- or *Sphaerella*-like type, and whose successive forms gradually increase in size, complexity, and sexual differentiation. *Volvox* itself has been well spoken of as "the culmination of Nature's attempt to evolve a higher organism out of a cœnobe". It was an attempt which failed, or rather which could not be carried any further than *Volvox* itself. A delicate, easily-ruptured *Volvox*-sphere could certainly not continue to exist if it were much more than a millimetre in diameter. As it is, the wall is often split, and all sorts of smaller organisms get inside, resulting in the more or less speedy collapse of the *Volvox*-colony.

But there are other series diverging from the *Chlamydomonadeæ*, and some at least of them have followed lines on which it was possible for higher and more varied plant-forms to be developed.

At the first stage along one of these lines of descent we find ourselves among forms in which the dominant phase of the life-history falls in a resting stage, either fixed or freely floating in the water. From this resting stage motile forms (zoospores), corresponding with the free-swimming *Chlamydomonas* individuals, are directly developed. These zoospores, after a short period of swarming, come to rest, often fixing themselves by their anterior end to some solid object. With little or no change in the constitution and appearance of the cell the main portion of the

life cycle is passed in this fixed condition, and cell divisions take place, the products eventually again developing flagella and being set free as zoospores. The genera *Chlorangium* and *Physocytium* are examples of the simplest form of this type of life-history. Forms with a rather more complicated structure in the fixed stage are found in the genera *Mischococcus* (a common form on the surface of threads of the higher Algæ), *Euglenopsis* (a newly-discovered American plant), and their allies. In these the protoplasm of the zoospore, after fixing itself and putting on a delicate cell-wall, pushes out the surface of its membrane away from the substratum, thus forming a tube of gradually increasing length, the apex of which is always occupied by the protoplasm. Division of the protoplasm and subsequent pushing out of the wall of the tube in different directions by the daughter-cells results in a branching of the hollow stalk, and in this way quite a considerable branching plant-body may be produced. Eventually some or all of the cells occupying the apices of the various branches of the tube acquire flagella and escape into the water as zoospores, which again settle on solid objects and give rise to new plants.

Other forms in which the cell derived from a zoospore multiplies by division, the products eventually again giving rise to zoospores, are *Schizochlamys*, *Botryococcus*, *Dictyosphaerium* and *Tetraspora*. In these, however, the immotile phase is not fixed, but forms floating colonies of various conformation. Into this topic we cannot enter further, except to remark that *Tetraspora* forms flat colonies of cells arranged in one plane and held together by the swollen mucilaginous cell-walls. Cell division takes place in planes at right angles to that of the colony. This type of colony is specially interesting, as it suggests the form of thallus found in *Ulvaceæ*, which in turn appears to lead on to the higher forms *Confervoidæ*.

Pleurococcaceæ.—More or less closely allied to the above-mentioned genera are others which do not form zoospores at all. These types with no motile phase in their life-cycle may be conveniently classed together as *Pleurococcaceæ*. The type-genus *Pleurococcus* contains some of the most widely-distributed algal forms known. *P. vulgaris* forms the bulk of the green coating of damp earth, tree trunks, palings, &c., in all regions of the globe. It consists of roundish cells, dividing in three directions in space and thus forming solid masses of cells hanging together in multiples of two, and often flattened by lateral contact. Each cell contains several parietal chromatophores which may, however, fuse together to form a single one. Resting akinetes are formed by the cells ceasing to divide, becoming spherical, and thickening their walls. At the same time oil appears in the protoplasm. It is probably mainly in this phase that *Pleurococcus* gets distributed by the wind from one place of growth to another. Owing to the resemblance of the akinetes of some of the confervoid Algæ to those of *Pleurococcus*, it has often been stated, and indeed is still held by some algologists that *Pleurococcus* itself is merely a growth-phase of these higher Algæ. But recent culture-experiments leave little room for doubt that *Pleurococcus* is a perfectly autonomous form, although it may often be associated with pleurococcoid stages of other Algæ. *Eremosphaera* is a pretty form, common in fresh water, with single floating spherical cells. Each cell contains numerous separate chlorophyll-

bodies, embedded in a parietal layer of protoplasm, and a nucleus suspended by protoplasmic strands in the centre of the cell. Multiplication is effected by division of the protoplasm into two daughter-cells which escape by rupture of the mother-cell membrane. *Scenedesmus* is another motionless floating fresh-water form. It consists of oblong cells united into groups of two, four, or eight, which lie side by side, palisade fashion. Some or all of the cells often possess straight or horn-like projections of their walls, which give the cell groups a very characteristic appearance. The single solid chromatophore occupies nearly the whole cell cavity. *Chlorella* is a genus whose cells are symbiotic with *Radiolaria* (yellow cells). Other forms live in a similar relation with certain Coelenterates and Platyhelminths. Several help to form lichens. Since the various genera of *Pleurococcaceæ* differ thus very widely in the form and structure of their cells, and indeed are only united by the negative character of the absence of zoospores, it is almost certain that they cannot be considered as forming a natural group. The various genera are very probably allied to different neighbouring groups from which they have been derived by the suppression of the habit of forming zoospores.

The *Endosphaeraceæ* are a small and very natural group of unicellular Algæ, characterized by their habit of living in the intercellular spaces of various higher plants. They possess motile zoospores, or gametes, or both, but the motionless cells produced from these do not undergo vegetative divisions. Very possibly they represent a separate line of descent from the Chlamydomonadæ, a line of descent in which the motionless cell has become the dominant phase in the life-cycle, and has been specially adapted to the new conditions of life, but differs from the motionless cells of the "Tetrasporaceæ" in directly forming zoospores without undergoing purely vegetative divisions.

Two forms of *Endosphaeraceæ* may be taken as illustrations of this type of life-history.

Chlorochytrium Lemnæ inhabits the intercellular spaces immediately under the epidermis of the leaves of *Lemna trisulca* (the Ivy-leaved Duckweed). Each plant consists of a single, thick-walled, oval cell with a parietal chromatophore containing numerous pyrenoids and a large central vacuole. Very numerous pear-shaped isogametes are formed by successive divisions of the protoplasm of the cell. Then a layer of substance outside the mass of gametes (probably the ectoplasm of the cell) begins to swell strongly, and bursts not only the cell-wall but also the superincumbent tissue of the Duckweed leaf, forming a sphere of mucilage in which the gametes begin to swarm and to conjugate in pairs. Spherical zygozoospores are thus produced; these escape from the mucilage, and after some free swarming in the surrounding water, settle on the boundary between two epidermal cells of a Duckweed leaf, draw in their flagella, put on a cell-membrane, and form a definite parietal chlorophyll-body with a single pyrenoid. After two or three days a delicate, colourless tube is put out, which forces its way between the two epidermal cells of the leaf, and reaches an intercellular space. The contents of the zygote slowly pass over into the apex of this tube, which gradually increases in size and assumes the

characters of a young vegetative cell, the original zygote-wall remaining on the surface of the leaf as a mere cellulose knob.

The generations rapidly succeed one another during the summer months, the last-formed cells of the season becoming packed with starch grains and passing the winter in this state. These resting cells can withstand desiccation, in case the pond in which the duckweed lives becomes dried up.

Phyllobium dimorphum forms large immotile cells between the tracheids of the vascular bundles in the leaves of the creeping Moneywort (*Lysimachia nummularia*). This plant lives in damp woods and other shady places. The Rhine plain in the neighbourhood of Strasburg, where *Phyllobium* was first found in the leaves of the Moneywort, is usually flooded during the month of June, partly by the rising of the river, and partly by the thunderstorms which usually occur about that time of the year. The *Phyllobium*-cells take this opportunity to form their gametes, which are of two distinct sizes, each cell producing gametes of one size only. After the escape of the gametes into the surrounding water conjugation occurs. The zygozoospores produced have only two flagella, the body and flagella of each microgamete being completely lost in the megagamete, just as the body of a spermatozoid is completely lost in the substance of the egg. After coming to rest on the surface of a *Lysimachia* leaf, and acquiring cell-membranes, the zygotes put out delicate tubes which enter the stomata of the leaf. If a leaf is infected by a few zygotes only, the tubes formed reach the vascular bundles, and forcing their way between the elements of the wood, grow forward in the bundles, branching when they branch, and attaining to a considerable length. Eventually, towards the end of the summer, the protoplasmic contents of each tube becoming concentrated in one spot, this part of the tube swells and is cut off from the remainder by the formation of transverse partitions. The swollen part of the tube thus forms a large cell which rests during the winter, and in the next summer will produce gametes. If, on the other hand, the leaf is infected by a large number of zygotes, most of the tubes never get any further than the intercellular spaces immediately under the stomata. In this position they form small resting cells in large numbers. These eventually form *zoospores*, which apparently behave, on germination, just like the zygozoospores. The dimorphism of the resting cells of *Phyllobium* thus depends directly on the *amount of space* at the disposal of the germ tubes. This conclusion can be confirmed by cultivating the germ tubes apart from the leaves of the host.

The purpose of the germ tubes of *Chlorochytrium*, *Phyllobium*, and their allies in penetrating the leaves of their hosts, seems to be simply that they may gain the advantage of a quiet protected place for their development. Just in the same way Diatoms and other unicellular forms often live comfortably in the empty cells of Algae, the intercellular spaces of the Bog-moss (*Sphagnum*), and similar situations. Only in the case of these Endosphæræ the association of the Alga with its habitat is invariable and adaptive, not merely casual and unrelated. But the Endosphæræ are not parasites in any sense. They take no food from their "hosts" nor do they exercise any appreciable influence on the latter. This is sufficiently proved by the

fact that *Lemna trisulca* lives quite happily and can flower when infested with *Chlorochytrium*, and that the germ tubes of *Phyllobium dimorphum* usually enter dead leaves of the Moneywort. Another form which always enters the living leaves of a river-weed, continues its course of development whether the leaves die or remain alive. It is not, however, difficult to imagine how a form like *Phyllobium*, living as it does in the vascular bundles of its host, might acquire a parasitic habit by tapping the food supplies. As a matter of fact certain confervoid Algæ are known whose presence results in the death of the leaves they inhabit, though probably not by direct appropriation of the food of the host.

Resembling the *Endosphæreæ* in possessing motionless cells which form zoospores but do not undergo vegetative divisions, are certain common fresh-water forms of which *Characium* and *Sciadium* may be mentioned. A plant of *Sciadium* originally consists of a single cylindrical cell whose contents breaks up into zoospores. These zoospores have acquired the peculiar habit of settling on the rim of the mother-cell, instead of seeking out fresh spots for their development. Each zoospore produces a single cell like the mother, so that a whorl of cells of the new generation is formed on the top of the original cell. This process may be repeated for two or three generations, after which the zoospores will settle on some other object and start fresh "plants".

The *Hydrodictyaceæ* are a group of Algæ which form immotile colonies. The cells of these colonies resemble the single cells of the forms we have just been considering in producing zoospores or gametes, but undergoing no vegetative divisions. The colony is formed by the joining together in a definite way of the group of zoospores formed in a single cell of the mother-colony. Each of these zoospores then develops into an adult vegetative cell.

The recently discovered genus *Euastropsis* (so called from its likeness to the Desmid *Euastrum*) is the simplest type of the family. It consists of two mitre-shaped cells joined to one another by their bases. Each cell contains a parietal chromatophore with a single pyrenoid, and a single nucleus. The contents breaks up by successive divisions into 2-32 zoospores, which escape from the cell surrounded by a general membrane. After oscillating for about a quarter of an hour, the zoospores become attached in pairs by their anterior ends. Each pair then takes on the characters of the two-celled colony.

Pediastrum (fig. 370⁶) consists of a disc of cells, of which the marginal ones are often drawn out into lobes or processes. The chromatophore is parietal with a single pyrenoid; there are numerous nuclei. The formation of zoospores is like that of *Euastropsis*, but their movement is more lively, and eventually all the zoospores formed in a single cell join together to form a new *Pediastrum*-colony (figs. 370⁷ and 370⁸). Gametes are formed in the same way as the zoospores, but are smaller and more numerous. They escape from the investing membrane, swim freely in the water, and fuse in pairs to form zygotes. From these zygotes new *Pediastrum*-colonies are produced indirectly, probably by a method like that obtaining in *Hydrodictyon*.

Hydrodictyon, the Water-net (figs. 370¹ and 370²) is a beautiful organism forming net-like colonies of cylindrical cells, which are joined end to end, forming the sides of the polygonal meshes. Each cell may be as much as 1 centimetre in length. A thin layer of protoplasm containing numerous small nuclei lines the wall and incloses a large central vacuole. The chromatophore, or chlorophyll-layer of the protoplasm, contains many pyrenoids, each surrounded by a sheath of starch grains. Fine-grained starch is also scattered through the substance of the chro-

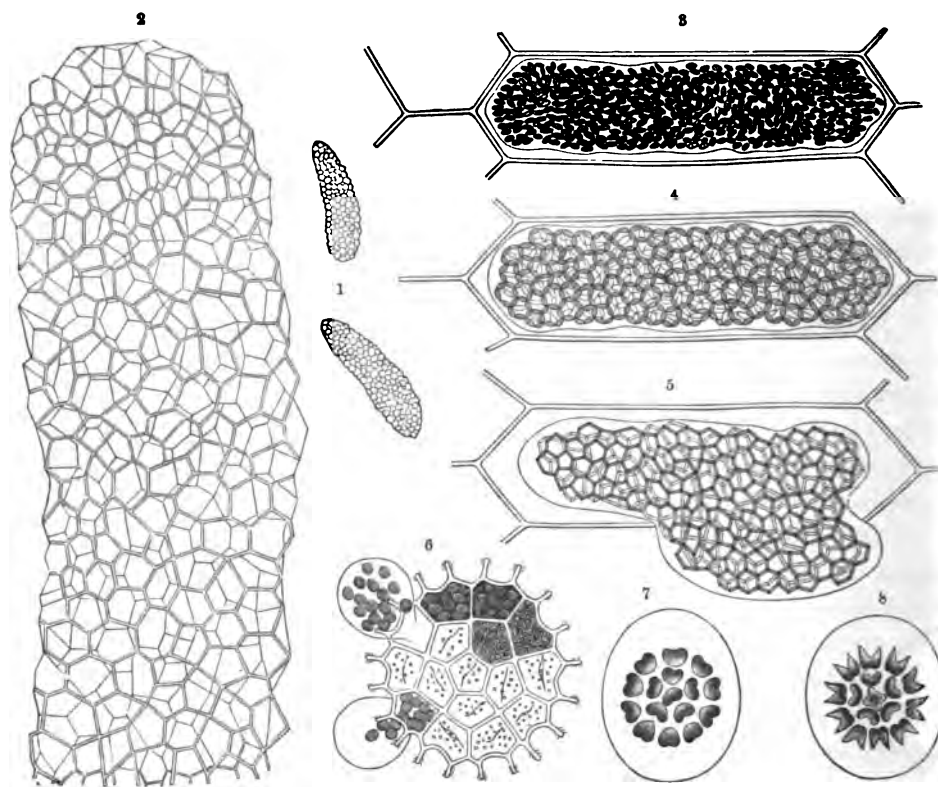


Fig. 370.—Hydrodictyaceae.

¹ The Water-net (*Hydrodictyon utriculatum*), nat. size. ² A portion of the same magnified 50 diameters. ³, ⁴, and ⁵ Formation of zoospores in a cell of *Hydrodictyon*, showing their union together, and escape as a young net; $\times 300$. ⁶ *Pediastrum granulatum*; development and escape of zoospores, the lightly-dotted chambers already vacated. ⁷ and ⁸ Zoospores after their escape arranged as a new *Pediastrum* plant; $\times 240$.

matophore. This stroma-starch appears in great quantity when growth is checked and assimilation remains active, disappearing again if assimilation is stopped. The pyrenoid-starch, on the other hand, seems to be withdrawn from the ordinary metabolism of the cell, since it is formed round each pyrenoid early in the life of the cell, and remains there under all circumstances, unless the cell is on the point of actual starvation in the dark, till the onset of reproduction. When zoospores are about to be formed the pyrenoids together with their starch disappear, and abundant stroma-starch appears. At the same time the nuclei multiply a good deal by division, and eventually the whole of the protoplasm divides to form a great num-

ber of zoospores. These zoospores, however, never become free like those of *Pediastrum*, but remain joined together by strands of protoplasm, and after a certain amount of shifting backwards and forwards, come to rest with their ends in contact. Each then gradually assumes the characters of a *Hydrodictyon*-cell, the young colony eventually escaping from the mother-cell (figs. 370³, 4, 5). Gametes are formed in the same way as zoospores, but are smaller and more numerous. The spherical zygote gradually increases in size, and its contents breaks up into 2-5 large zoospores, which develop into large cells with pointed processes, the so-called *polyhedra*. In the interior of each polyhedron an embryonic *Hydrodictyon*-net is developed from swarm-spores, and in the cells of this ordinary *Hydrodictyon* colonies are found.

It has been shown experimentally that any *Hydrodictyon*-net above a certain size and age is capable of producing either zoospores or gametes, and that the stimulus to the formation of one or the other is given by external conditions. Thus bright light, fresh water rich in inorganic nutritive salts, and fairly high temperatures, are favourable to the production of zoospores, while the reverse of these conditions, and especially the presence of organic substances, such as sugar, tend to make the cells of a net produce gametes. The conditions favourable to zoospore-formation are also of course, favourable to active vegetative growth, and no doubt the abundant formation of new protoplasm is a necessary preliminary to the production of zoospores. A slight check to the processes of assimilation and growth is apparently necessary in order to give play to the zoospore-forming forces. Thus, experimentally, a change from a strong solution of nutritive salts to fresh water will induce the formation of zoospores in nets which would simply have gone on growing if left in the nutritive solution. A similar check is probably given by the waning light in many Algae in which zoospores are produced at night. For the production of gametes, on the other hand, an actual reversal of the conditions favourable to growth is necessary. In nature this probably happens when by very active growth the whole of the water of a pool is filled with nets, the inorganic food and oxygen are exhausted, and the normal chemical processes of the cell receive a check. The formation of gametes and zygotes under these conditions is obviously adaptive, since the zygote can, although it need not, rest during several months till the conditions are quite altered. We may therefore conclude that, whereas zoospores are especially designed to multiply and distribute the species, zygotes are intended to preserve it under unfavourable conditions. It is probable that the production of large zoospores and polyhedra is a necessary part of the life-cycle following the germination of the zygote, and cannot be altered by the incidence of different conditions.

Alliance VII.—Siphonæ.

Thallus consisting of a tube, often much branched, and containing many nuclei. This tube is the production of a single cell, but in the more complicated forms is often shut off into compartments by transverse septa. Reproduction by zoospores

and planogametes, or spermatozoids and eggs: in very many forms no reproductive cells are known. The higher forms of Siphonæ often produce plant-bodies of very definite and characteristic external form, and of considerable size. In some cases these simulate the external form of various higher plants.

Families: *Botrydiaceæ*, *Phyllosiphonaceæ*, *Vaucheriaceæ*, *Bryopsidaceæ*,
Caulerpacææ, *Codiaceæ*, *Valoniaceæ*, *Verticellatæ*.

Botrydiaceæ.—*Botrydium granulatum* is a little plant found growing especially on loam at the damp edges of ponds and ditches. It consists of a club-shaped or balloon-shaped green shoot-portion, about 1-4 millimetres in diameter, continuous with a simple or branched tubular colourless root-portion which is embedded in the substratum. The entire plant consists of a single cell, that is to say, its cavity is continuous throughout. The wall is lined with a thin layer of protoplasm, which contains many nuclei, and, in the shoot, a net-like chlorophyll-layer.

Botrydium can reproduce itself in very various ways, according to the incidence of external conditions. The simplest form of propagation is by budding, which takes place under conditions favourable to the ordinary vegetation of the plant. The shoot-portion of a small vegetative plant sends out a process which swells to the size of the mother shoot, puts out a colourless root, and is then constricted off to form a separate plant. But if the plants are covered with water they cannot go on growing comfortably, and accordingly the protoplasm breaks up to form a number of zoospores, each with a single flagellum and two lateral chromatophores. The mass of zoospores is subjected to considerable pressure by the swelling up of a ring-like area of the wall, and the tension becomes so great as to rupture the wall in the centre of the ring and expel the mass of zoospores into the water. On damp soil the zoospores come to rest, and germinate to form new plants. If a zoospore cannot escape from the water it enters on a resting stage, which gives rise to a new plant directly it finds itself on damp soil. Further, if a young plant is exposed to bright sunlight, its protoplasm breaks up into a number of spherical cells, each of which puts on a cell-wall. If now these spherical cells (*gametangia*) are placed in water, the contents of each breaks up into spindle-shaped, biflagellate gametes, which conjugate in pairs to form zygotes. These zygotes can rest for a longer or shorter time, but if placed on damp earth they at once germinate to form new plants. If, on the other hand, the gametangia are placed in water after being kept for two years they give rise to biflagellate cells which rather resemble the gametes, but which on damp soil germinate directly to form vegetative plants. Finally, if the gametangia are at once placed on damp soil, their contents does not break up, but the whole gametangium germinates and produces a plant. Supposing a large *Botrydium*-plant, with a balloon-shaped shoot, be exposed to insolation (bright light) its contents, instead of forming gametangia, travels down into the root, and the protoplasm there divides to form rows of *root-cells*, each with an independent cell-wall. If a root containing root-cells be placed in water, the protoplasm of each cell breaks up into a number of zoospores: if the root be placed on damp earth each

root-cell sends out a tube which grows into a young vegetative plant: if left in the soil, the latter remaining damp, each root-cell germinates to form a peculiar thick-walled plant called a *hypnosporangium* which can withstand desiccation, and which in water gives rise to a number of zoospores.

The above facts may be briefly expressed by saying that any stage in the life-history of *Botrydium* tends (1) on damp soil to form vegetative plants, (2) in water to form zoospores or gametes, (3) in dry conditions to form resting cells. There can, then, be no doubt that here, as in the case of *Hydrodictyon*, we are justified in saying that the form which any given set of conditions tends to produce is adapted to meet those conditions.

Phyllosiphonaceæ.—*Phyllosiphon Arisari* is an Alga living in the intercellular spaces of the leaves of *Arisarum vulgare* in Southern France and Italy. Its thallus consists of a much-branched tube, the parietal protoplasm containing many nuclei and small disc-shaped chromatophores. Unlike the *Endosphæreæ*, the presence of *Phyllosiphon* has a considerable effect on its host, causing blotches of dead tissue to appear in the leaves. As the Alga can presumably assimilate quite well for itself, this destruction of tissue is probably caused by withdrawal of water from the cells of the host. The only kind of reproductive cells which *Phyllosiphon* is known to produce are aplanospores (non-motile spores). These are formed by the division of the whole of the protoplasm of the thallus. They are extruded by the swelling of the inner membrane of the tube which bursts the outer membrane just under a stoma, shooting out a jet of mucilage in which the aplanospores are embedded. The latter germinate directly, the germ-tubes entering the leaf between two epidermal cells.

Vaucheriaceæ.—This family includes only the well-known and widely distributed genus *Vaucheria*. Different species of *Vaucheria* grow in brackish and fresh water, both running and stagnant, or in the air in damp situations. The thallus consists of relatively coarse branched tubes, quite visible to the naked eye. The interior of the tube is lined by a layer of protoplasm containing numerous disc-shaped chlorophyll-grains and many nuclei. The *Vaucheria*-plant is fixed to its substratum by short-branched, colourless processes, but, except in connection with the formation of reproductive cells, transverse septa are not formed in the tubes.

The gametes of *Vaucheria* are formed in special organs, known as antheridia and oogonia. The distinction of sex is very strongly marked, the male gametes or spermatozooids being very small oval cells, each with two laterally inserted flagella, while the female gametes or eggs are very large and quite motionless. The antheridia are often spirally curved branches of the main tube, a transverse wall separating the upper part of the spiral, the antheridium proper, from the lower part, which is continuous with the cavity of the vegetative tube. Sometimes, however, the antheridium is straight and club-shaped, and in other cases it may be separated from the main tube by an intermediate cell. The thirty-five species of *Vaucheria* are classified according to the characters of their antheridia. The oogonia are

ovoid or spherical, and usually possess a lateral beak. While the antheridium produces a large number of the small spermatozooids, the oogonium gives rise to a single large egg. An account has already been given of the process of fertilization (see p. 58, and figs. 204⁵ and 204⁶, on p. 53).

Vaucheria also produces peculiar zoospores, whose development and subsequent behaviour have been described on pp. 23 and 24 of vol. i. (see Plate I. a-d). The cilia with which the surface of the zoospore is clothed are arranged in pairs, and in the colourless external layer of protoplasm just below each pair of cilia is situated a single nucleus. This suggests that the zoospore of *Vaucheria* is to be regarded as really equivalent to a great many zoospores which have not separated during development, each nucleus, with its pair of cilia and a certain amount of chlorophyll and protoplasm, representing an ordinary zoospore. It has been found that if, as often happens, the zoospore breaks into two during its struggles to escape from the end of its tube, the front part rounds itself off and swims away, behaving just like an entire zoospore. In some species of *Vaucheria* the zoospores are only partially clothed with cilia and come to rest soon after their escape. In yet others they have no cilia at all, and either escape by dissolution of the end of the tube, or germinate *in situ*. Here then we have a transition from the formation of active zoospores to the production of passive aplanospores.

The occurrence and form of reproduction is here even more entirely under the control of conditions than is the case in *Hydrodictyon*. The age and size of the plant are no longer factors, since sexual organs and zoospores can be formed on quite short germ-tubes. Cultivation of the plant in a solution rich in inorganic food-salts always gives it a tendency to produce zoospores, but the immediate stimulus to their formation is given by a distinct *change* in the conditions, just as is the case in the Water-net. In *Vaucheria* this change is especially necessary, since each zoospore is formed in the apex of a tube, and apical growth must be stopped in order to allow free play to the zoospore-forming forces.

The nature of the change, so far as regards the medium, is apparently immaterial—it may be a change from running water to still water, or from a damp atmosphere to water, or in the temperature or concentration of the culture-solution, but it is a change from light to darkness which is especially effective. This is quite contrary to the case of *Hydrodictyon*. The presence of water and a temperature between 3° and 26° C. are absolutely necessary conditions of zoospore-formation.

The former condition is obviously adaptive. The formation of sexual organs is specially induced by the replacement of inorganic salts by organic substances (*e.g.* sugar), just as in the case of the gametes of *Hydrodictyon*, but antheridia and oogonia, which are formed much more frequently and easily than are the Water-net gametes, often appear in the presence of salts, and when growing in a damp atmosphere. Light and a temperature above 3° C. are absolutely necessary conditions.

The most striking point in the physiology of the reproduction of *Vaucheria* is the prominent part played by the sexual organs. These are undoubtedly the principal means of propagation the plant possesses, the zoospores, which usually fulfil this

role, having fallen to a subordinate position. Only in forms like *Vaucheria clavata*, adapted to life in rapidly-flowing water, have the zoospores a primary importance. Sexual reproduction is here difficult, and zoospores are always produced in abundance on the slightest change of conditions.

Bryopsidaceæ.—This family consists of marine, mostly tropical, forms. The plant-body of *Bryopsis* has quite a definite form, and consists of a tube forming the main axis, fixed below by short root branches, and bearing above in acropetal succession a series of branches, some of unlimited, some of limited growth. In these latter are formed swarming cells which are of two sizes, the smaller being yellowish, while the larger have each a green chromatophore. It seems very probable that these are anisogametes, but their conjugation has not been observed.

Derbesia is a genus like *Bryopsis* in many respects, but with special zoosporangia which produce curious zoospores, each with an anterior crown of cilia.

Caulerpaceæ.—The genus *Caulerpa* contains nearly one hundred species, which present the most varied external forms, simulating those of many of the higher plants, such as Mosses, Ferns, Mare's-tails, Cactuses, Conifers, &c. Each plant, however, consists simply of a single much-branched but uninterrupted tube, the branches taking the forms of roots, leafy shoots, &c. The tube is supported internally by a complicated system of "beams" of cellulose which run out from the walls.

The *Caulerpas* live mainly in tropical and subtropical seas. They often grow together in large masses, forming great beds of sea-weed, their creeping stems or "rhizomes" extending many yards. No reproductive cells have as yet been found in any of them, multiplication taking place apparently solely by the breaking off of parts of the thallus, which drift and fix themselves elsewhere.

Codiaceæ.—Under this name we may conveniently place together a group of forms specially characterized by a thallus consisting of richly-branched tubes, which are interwoven to form a mass of more or less solid character, which possesses in each genus a definite and characteristic external conformation. Thus, *Penicillus* has a long cylindrical "stalk" fixed below by "rhizoids" and bearing above a head of free dichotomously branching radiating filaments. The older parts of the stalk are strongly incrustated with calcium carbonate.

Udotea has a stalk often creeping and branching, bearing flat fan-shaped fronds. Spherical bodies, the nature of which is unknown, are borne on short side branches of the tubes of which the frond is built up. *Halimeda* possesses a thallus mainly composed of series of heart- or kidney-shaped segments, which give many of the species the appearance of an *Opuntia*. There is usually a considerable deposit of calcium carbonate covering the thallus. Roundish structures, produced in grape-like bunches on the edges of the segments, liberate swarming cells whose behaviour has not been followed.

Codium has no well differentiated stalk or segments; the thallus is very various in form, and is differentiated into a well-marked pith and cortex, the tubes being mainly longitudinal and loosely packed in the former, while the latter consists of club-shaped closely-packed branches arranged at right angles to the surface. In

certain branches of the latter swimmers of two sizes are produced. Analogy would lead us to suppose that at least the smaller of these are gametes, but their behaviour has not been observed. Some species of *Codium* (e.g. *C. tomentosum*, with a dichotomously branched furry thallus) occur on our own coasts. The remaining Codiaceæ are largely tropical, but very widely distributed.

Valoniaceæ.—We may include in this family an assemblage of genera whose thallus consists of a branching tube, usually forming transverse walls, but with no interweaving of the branches such as we get in Codiaceæ.

The simplest type is found in *Valonia*, a form which at first consists of a single club-shaped cell, which produces a whorl of branches at its upper end. Each of these may again produce a whorl of branches of the second order.

A group of very beautiful genera form leaf-like structures, the branching of the thallus taking place in one plane. *Struvea* consists originally of a single cell, which grows apically and becomes divided by transverse walls into a series of segments. Each of these segments bears a pair of branches coming off right and left, and each branch behaves like the main axis. The secondary and tertiary branches thus produced come into contact, fixing themselves one to another by means of curious little rosette-like organs called *tenacula*, and the whole thus forms a net-like structure with larger or smaller meshes between the branches. The definite usually oval form of the "leaf", of which the main axis forms the midrib, and the primary branches the principal veins, is due to the latter, after they have attained a certain length, ceasing to produce branches on the side towards the base of the thallus, and at the same time bending forwards and inwards to join the primary branch next in front.

Struvea delicatula sometimes lives in the tissue of a Sponge belonging to the genus *Halichondria*. There is a reciprocal effect on the form of the two organisms, the Alga only taking on the characteristic *Struvea*-form when part of its thallus grows out clear of the body of the Sponge. In consequence of this it was for some time not suspected that this sponge-inhabiting Alga had any connection with *Struvea*. Neither organism seems to suffer from the association, and there is some evidence for regarding it as a case of true symbiosis.

Anadyomene is another very beautiful form resembling *Struvea* in the construction of its thallus, but with no meshes between the cells. It consists of two kinds of cells, the more elongated form the "ribs" of the thallus, the smaller and more rounded make up the intermediate tissue.

The genus *Boodlea*, in which the branching takes place in more than one plane, forms a transitional form connecting these genera with *Cladophora*, which is usually regarded as belonging to the Confervoideæ.

Verticillatæ.—In this group of the Siphonæ the thallus consists of a long cylindrical undivided stalk, fixed below by rhizoids, and bearing above acropetal whorls of simple or branched appendages of limited growth. In some of these appendages gametes may be produced; zoospores are apparently absent. It includes two sub-families, the Acetabulariæ and Dasycladæ.

Acetabulariæ.—Fertile and sterile appendages distinct. *Acetabularia mediter-*

ranea: the lower part of the long cylindrical stalk is incrustated with calcium carbonate, and fixed to its substratum by short irregularly branched rhizoids. The rhizoid-bearing portion is called the *foot*, and below it there is a thin-walled branched continuation of the stalk, called the *basal division*. Near the apex of the stalk are borne 1-4 whorls of polychotomously branched sterile appendages, which soon fall off.

Above these is an umbrella-shaped whorl of simple appendages in lateral contact, whose cavities are not shut off from that of the stalk. The whole of the upper part of the plant dies off each autumn, only the foot and basal division remaining alive through the winter. In the spring a new shoot is produced. Apparently after several years the contents of each simple appendage of the umbrella (which may now be a centimetre or more in diameter) divides up into a number of oval bodies, each surrounded by a fairly thick wall and containing chlorophyll and starch. These are the *gametangia*. After their escape by the dissolution of the umbrella, the contents of each divides up to form a number of gametes. Considerable pressure, caused by swelling of the ectoplasm and osmotic tension in the vacuole of the gametangium, bursts off a lid at one end, and the gametes escape. Conjugation only occurs between gametes derived from distinct gametangia.

Dasycladææ.—No distinction between fertile and sterile appendages. *Dasycladus* has a single stalk-cell fixed below like *Acetabularia*, but bearing very numerous whorls of appendages, which stand so close together as to give the entire plant a resemblance to a minute fox's brush. Each appendage bears a terminal whorl of branches, and in the middle of these is a shortly-stalked, nearly spherical gametangium. The gametes conjugate, but apparently only with those from certain other plants. This fact at first led to the supposition that we had here a physiological distinction of sex in gametes, which in external appearance are all alike. This is, however, quite an unjustifiable and unnecessary assumption. We have no right to predicate sexual differences between gametes which do not show any of the well-recognized characters of male and female reproductive cells. The tendency to avoid pairing with closely related gametes, which we may call *exogamy*, is quite a distinct phenomenon, not only among isogamous Algæ, but also among many of the higher plants, where it coexists with strongly-marked sex. The phenomena of self-sterility is an extreme case of this.

Neomeris and *Cymopolia* are two tropical and subtropical genera, whose thallus is very strongly incrustated with calcium carbonate. The arrangement of the branches resembles that found in *Dasycladus*, but on the ends of the younger ones hairs are borne, which serve to protect the growing apex of the plant. In *Cymopolia*, of which the main stalk branches, and the thallus attains a considerable size, these hairs are borne by simple branches produced on special constricted and uncalcified zones of the stalk. The apices of the secondary branches are in both genera swollen up, and in close lateral contact, thus forming a continuous surface on the exterior of the plant. The calcium carbonate is deposited as a thick layer underneath these swollen ends.

A whole series of fossil forms from the chalk and tertiary deposits serve to connect the various existing types of these and allied genera.

Alliance VIII.—Confervoides.

The Algae included under this alliance possess a type of thallus composed of distinct and separate cells. These cells are united usually into linear series, which form branched or unbranched threads. In a few families, however, cell-division takes place in two, or even three, dimensions, resembling some Protococcoideæ in the formation of cell-surfaces or cell-masses. Zoospores are produced by nearly all confervoid forms. Aplanospores and akinetes are common. The gametes may be isogamous, or they may show marked sexual differentiation.

Families: *Ulvaceæ*, *Ulotrichaceæ*, *Cylindrocapsaceæ*, *Ædogoniaceæ*, *Cladophoraceæ*, *Gomontiaceæ*, *Sphaeropleaceæ*, *Chaetophoraceæ*, *Trentepohliaceæ*, *Mycoidaceæ*, *Coleochaetaceæ*.

Ulvaceæ.—This family is usually regarded as the lowest of the confervoid series. It is characterized especially by forming cell-surfaces instead of filaments. Zoospores with four flagella and isogametes with two, as well as akinetes, are formed in the group. *Monostroma* very much resembles *Tetraspora* among the Protococcoideæ, from which we may suppose the confervoid forms to have arisen in evolution. The thallus consists of a single layer of roundish or angular cells. In germination, the zygote divides to form a small hollow sphere, which splits, and extends itself to form a flat plate. At first fixed by rhizoids, the thallus later floats freely in the water. The chromatophore is a parietal plate, covering more or less of the cell-wall, and contains a single pyrenoid. Gametes (which may develop without conjugation), or zoospores may be formed in almost any cell of the thallus.

Ulva differs from *Monostroma* in possessing a thallus of two layers of cells, those of each layer dividing independently of the other. The zygote germinates to form a fixed cell thread, which later on produces the two-layered thallus. *Ulva latissima* (the Green Laver or Sea-lettuce) is very common on the rocks of our coasts near high-tide mark. It forms large green wavy fronds firmly fixed to the substratum. It is sometimes used as an article of food.

Enteromorpha is a large genus, several species of which are common on our coasts, and some in fresh water. The thallus forms a branched hollow tube, the wall of which is one cell thick. Any cell of the thallus may act as the apical cell of a branch. The apex of the branch is solid, but the cells soon round themselves off to form the wall of the tube. The gametes and zoospores resemble those of *Monostroma* and *Ulva*.

Letterstedtia is a Cape and Australian form much like *Ulva*, but with a deeply-lobed thallus. Zoospores are produced only in the cells of the lobes.

Ulotrichaceæ.—This family contains several genera common in fresh water, and some marine forms. The thallus consists of an unbranched filament of cells seldom much longer than they are broad. The chromatophore is single, parietal, and of

very various form. Zoospores are formed in most genera. Gametes, where known, are motile and isogamous. Aplanospores and akinetes are very commonly formed, under unfavourable conditions.

Ulothrix (fig. 371), the best-known genus, possesses cells of very variable length. The chromatophore, which contains several pyrenoids, is an interrupted cylinder, and may or may not occupy the whole length of the cell. When the conditions are suddenly changed, zoospores or gametes are very readily formed, the former 1-4 the latter 4-32 in a cell. According to the size of the mother-cell and the number of divisions taking place, the size of the zoospores and gametes varies greatly, the

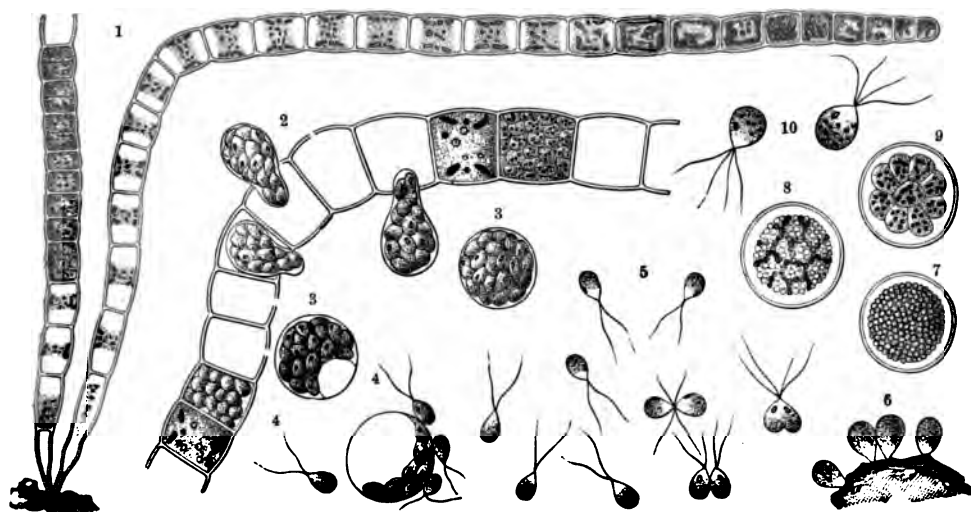


Fig. 371.—*Ulothrix zonata*.

1 Two filaments of this plant. 2 Escape of gametes in packets. 3 Spherical packet of gametes free from the filament. 4 Separation of the gametes. 5 Gametes swimming about and pairing. 6 Products of pairing of gametes (zygotes) attached to substratum. 7-9 Zygote giving rise to zoospores. 10 Two zoospores. 1 $\times 250$; 2-10 $\times 400$. (Partly after Dodel-Port.)

only constant distinction between them being the number of flagella, which in the zoospores are four, in the gametes two (cf. figs. 371¹⁰ and 371⁵). The zoospores or gametes escape from the mother-cell through a hole in the wall. They are surrounded by a bladder derived, probably, from ectoplasm. The swelling of this in the water helps to drag them out of the cell-cavity. The tension of the vacuole of the mother-cell, which is visible among the zoospores or gametes as a smaller bladder, also assists in pressing out the mass (figs. 371^{2,3,4}). The zoospore settles on some solid object, and, after putting out a short root-process from its colourless anterior end, produces a new cell-thread. Some of the gametes develop parthenogenetically, in which case they germinate just like zoospores, but produce usually smaller and weaker plants. The gametes which conjugate (see figs. 371⁵ and 371⁶) produce zygotes which sink to the bottom of the water, and after a period of rest grow into unicellular plants, each of which forms 2-14 zoospores (figs. 371^{6,7,8,9}). These probably give rise to ordinary plants.

The asexual generations of *Ulothrix* are produced during the autumn and winter, gametes being formed in spring, and the zygote resting through the summer. This course of events differs from that obtaining in most Algæ with a similar life-history. *Ulothrix* seems especially adapted to life in cold water.

Hormidium is a genus whose members grow largely on damp earth, tree trunks, &c. The chromatophore is solid, with radiating processes and a central pyrenoid. The cells of some species divide longitudinally, so as to form threads two cells broad.

Various other genera are common in fresh water.

Cylindrocapsaceæ.—*Cylindrocapsa* forms unbranched threads of short cells with very thick walls, each thread being fixed in the young state by a cellulose foot. The gametes show a considerable sexual differentiation. The males are pear-shaped, elongated, yellow, with two flagella at the anterior end. They are produced two in an antheridium, which is formed by the division of an ordinary cell into two or four. The protoplasm of an ordinary cell rounds itself off directly to become an egg, the wall swelling and bursting at one side to allow of the entrance of the spermatozooids. Parthenogenesis also occurs.

Edogoniaceæ.—*Edogonium* has a thallus consisting of an unbranched thread, of rather long cells, of which the basal one is fixed to some solid object. The chromatophore often forms a continuous parietal layer containing several pyrenoids. All the cells, except the basal one, are capable of division. When division is going to occur a rim of cellulose is formed inside the cell close to the upper transverse wall. After the nucleus has divided, and the new transverse wall is formed, the rim is opened, as it were, by a circular cut from without, and the tension of the cell causes a pulling-out of the substance of the rim. The result is the intercalation of a new cylindrical piece of cell-wall in the upper daughter-cell. The young transverse wall now moves up to the lower edge of the intercalated piece of membrane. The latter soon acquires the ordinary thickness of a side wall, but the segment of the old cell-wall above the spot at which the rim was formed remains projecting beyond the new piece like the eaves of a house beyond its side walls. After the cell has divided again, another projecting piece will be left in the same way, and the series of eave-like projections so formed are a very characteristic feature of the cells of an *Edogonium*-thread. The zoospores of *Edogonium* are formed singly in the cells of a thread. The entire cell-body, with the exception of the ectoplasm, rounds itself off and escapes from the cell by a split in the wall. An anterior circlet of cilia surrounds the colourless "mouth place," of the zoospore. In germination, the zoospore fixes itself by the mouth place, sending out short fixing processes, puts on a cell-membrane, and then grows out to form a new thread.

The gametes of *Edogonium* are sexually differentiated.

The oogonium is formed by the swelling-up of the uppermost daughter-cell after a division. The contents round off to form a single large oosphere. Either a round hole appears in the wall, or a circular split is formed at the upper end of the oogonium, the part of the filament above rotating through a few degrees so as to

leave an opening. A certain amount of the protoplasm of the oosphere is extruded at this spot, and forms a sort of canal of mucilage, through which a spermatozoid passes in fertilization. The spermatozoids are produced one or two in an antheridium, which are short cells poor in chlorophyll, formed by the repeated division of certain cells of a thread. The spermatozoids resemble small zoospores. In some cases they are not produced directly from the cells of a thread, but the latter give rise to special zoospores called *androspores*, which escape and settle either on or in the immediate neighbourhood of an oogonium. The androspore then germinates, producing a small structure called a *dwarf male*. This consists of a very few cells, one or more of which become antheridia, and opening by a lid, gives rise to spermatozoids, one of which pierces the canal of the oogonium, and fuses with the oosphere. The oospore, which is of a red or brown colour, produces four zoospores in germination.

Bulbochæte is a genus resembling *Edogonium* in its life-history, but consists of a branched thread, only the basal cell being capable of dividing. The cells bear characteristic hairs, swollen at the base, whence the name of the genus.

Species of *Edogonium* and *Bulbochæte*, which are both genera of considerable size, are found in our ponds and ditches.

The next three families are distinguished from all other *Confervoidæ* by possessing more than one nucleus in each cell.

Cladophoraceæ.—*Cladophora* is a very widely distributed genus, inhabiting both fresh and salt water. A great number of species have been described, but it is doubtful whether many of the forms are entitled to specific rank.

The thallus has a very characteristic habit. It is fixed below by an elongated basal cell, and is profusely branched, sometimes forming a spherical mass. The elongated cells possess parietal chromatophores, which cover the whole cell-wall, and possess many pyrenoids. Sometimes the chlorophyll-layer is separable into distinct angular plates. There are many nuclei in the layer of protoplasm immediately within the chlorophyll.

Many zoospores are produced in each cell. The nuclei divide a good deal, the pyrenoids disappear, and the protoplasm then divides into a number of separate masses, each of which forms a single zoospore with either four or two flagella. Gametes with two flagella are formed in many species quite like the zoospores. The zygote germinates directly to form a new *Cladophora*-plant.

The *Cladophoraceæ* show on the one hand a transition to the *Siphonææ*, and on the other, through certain genera with unbranched thallus and few nuclei in each cell, to the *Ulotrichaceæ*.

Gomontiaceæ.—*Gomontia polyrhiza* is an isolated form which perforates the shells of various marine molluscs, such as the whelk, the oyster, the mussel, &c. The thallus radiates on the surface of the shell, and sends branches into the substance, gradually disintegrating it. Certain branches become zoosporangia or aplanosporangia; these lose their attachment to the thallus and form fresh rhizoids. The zoospores are pear-shaped, and germinate directly to form a new thallus.

Sphæropleaceæ.—*Sphæroplea annulina* is a curious Alga which appears occasionally on flooded fields or in other situations. Its thallus consists of simple threads of cells which are of very various length, sometimes enormously long. The side walls are thin, but the transverse walls are often thick, and both are liable to have curious thick and quite irregular projections of cellulose. The chromatophores form irregular rings at intervals, and contain many pyrenoids. There are many nuclei, and several variable vacuoles in each cell. All the cells may produce sexual organs, the threads being either monoecious or dioecious. The contents of the cells which become antheridia become yellow-red, and break up to form a great number of elongated, pointed spermatozooids. These escape through small holes in the wall. In the oogonia the protoplasm divides to form one or two series of spherical oospheres, each with a colourless spot. The oospore has three membranes, of which the outermost is folded so as to give the oospore a star-like appearance.

In germination the oospore produces 1–8 zoospores, which have a green posterior and a pale-red anterior end. Each eventually stretches itself to form a spindle-shaped cell, and a multiplication of nuclei and pyrenoids takes place before transverse divisions occur and a new *Sphæroplea*-filament is produced. Parthenogenesis occurs, but apparently no zoospores are formed other than those produced in the germination of the oospore.

Chætophoraceæ.—This family contains forms with a branching thallus, the branches often ending in fine hairs. The chromatophore is parietal, with one or more pyrenoids. Zoospores with two or four, and gametes with two flagella are produced.

Stigeoclonium, *Draparnaldia*, and *Chætophora* are three genera common in fresh-water in this country, and all very slimy to the touch. In the first-named genus the thallus is fixed by means of a basal disc of cells, the *sole*; the branching is simple and irregular, the branches often ending in long multicellular hairs. *Draparnaldia* shows a marked distinction between axis and appendages. The axial cells are much larger, and at the same time poorer in chlorophyll than those of the branches. The branches come off in bunches, and often end in many-celled hairs. The chromatophore possesses many pyrenoids varying in number according to the size of the cell. *Chætophora* possesses a thallus whose threads radiate and branch in all directions. The whole is surrounded by a mucilaginous investment of considerable firmness, sometimes almost leathery in consistence, so that a *Chætophora*-plant has the appearance of a slimy green ball.

There are several other genera belonging to this family, many of them being epiphytic or endophytic. *Entoderma* lives in the cell-membranes of the Brown Sea-weed *Ectocarpus*.

Trentepohliaceæ.—This family differs from the last in possessing no hairs, and in forming its zoospores in special zoosporangia.

Trentepohlia is a fairly large genus containing forms mostly living in the air on damp stones and similar situations. The thallus consists of rounded thick-walled cells, and is dichotomously or irregularly branched, partly creeping, partly upright.

The chromatophores are many, disc-like, and angular, with no pyrenoids. The cell-contents is usually much marked with hæmatochrome. The zoosporangia and gametangia are usually terminal, often swollen cells. The gametes and zoospores are much alike. *Trentepohlia Iolithus*, growing on damp stones, is known as the "Violet-stone" from possessing a scent which recalls that of violets. *T. umbrina* is often attacked by lichen-forming Fungi. *T. spongophila* inhabits the jelly of *Ephydatia* (*Spongilla*) *fluviatilis* in a certain volcanic lake in Sumatra. The situation is very advantageous to the Alga, but the Sponge seems to suffer from the piercing of its tissue by the guest. *Trichophilus* is a nearly allied form which lives in the hollow hairs of the Three-Toed Sloth.

Mycoideaceæ.—These are epiphytic or parasitic forms nearly allied to the two preceding families, and probably derived from one of them. They form regular discs of cells often attached to the host by much-branched unicellular rhizoids. The disc grows by regular divisions of its marginal cells. Zoospores and sometimes gametes are formed in all or some of the cells.

Chatopeltis forms very regular discs of cells on fresh-water plants in Europe.

Mycoidea (*Mycoidea parasitica*) forms discs of cells between the cuticle and epidermal cells of Camellias, Rhododendrons, &c. in the East Indies and South America. In this position it withdraws a good deal of water from the tissue of the leaf, and this leads to the dying of the leaf-cells in a gradually increasing area round the parasite. Eventually a hole is formed right through the leaf, and the *Mycoidea*-thallus occupying a position all round the area of dead tissue continues to increase. Zoospores are only formed in the wet season, at which time alone have they any chance of swarming and germinating on the surface of the leaf. In this position primary (embryonic) discs are formed, many of which die, and others are attacked by Fungi to form Lichens, but some succeed in sending processes through the cuticle and establishing themselves below.

Coleochætaeæ.—This family contains a single small genus, *Coleochæte*, which forms radiating, dichotomously branching rows of cells, usually on the surface of other plants in fresh-water. If the cell-rows are in lateral contact, a close disc is formed (*C. scutata*), if separate a looser one (*C. soluta*), or the branching may be rather irregular (*C. divergens*). The chromatophore is parietal and disc-shaped, and contains a single pyrenoid.

Zoospores can be produced in all or only the end cells of the rows. A single one is formed from each cell. In germination a new plant is directly formed.

Coleochæte is oogamous, the plants being either monœcious or diœcious. The oogonium is always formed from the end cell of a row. The cell swells and puts out a narrow tube which opens at the end, and extrudes a drop of mucilage. The protoplasm of the swollen basal part then rounds itself off. In the forms with a disc-shaped thallus, the antheridia are produced by the division into four of the members of certain cell-groups. Each daughter-cell (antheridium) then liberates a single spermatozoid. In the branching forms certain end cells form flask-shaped swellings (antheridia), which are cut off from the mother-cell by transverse walls.

Each antheridium then liberates a spermatozoid. Fertilization has not been observed, but there can be no doubt that a spermatozoid passes down the neck of the oogonium and fuses with the oosphere. Subsequently the neck of the oogonium breaks off, the oospore puts on a cell-wall, and the neighbouring cells branch so as to form a closely investing cortex of cells round the oospore. The contents of these cortical cells turn red-brown; and after a resting stage the cortex comes off, the oospore having in the meanwhile divided to form a disc of cells, each of which gives rise to a zoospore, which escapes and germinates to form a new plant.

The structure of the oogonium, and the formation of a cortex round the oospore, as well as the formation of "carpospores" by the latter, recall the simpler Red Sea-weeds, a group which some authorities consider to be derived from some form like *Coleochaete*.

The indirect formation of new plants by the products of division of the zygote, a phenomenon we have already met with in *Pandorina*, *Hydrodictyon*, *Ulothrix*, *Edogonium*, and other forms, is probably the means by which the sporophyte generation of Mosses and Liverworts arose. At first the zygote gave rise at once to spores, but later on a certain amount of sterile tissue was produced in addition, and this formed the body of the sporophyte.

Alliance IX.—Conjugatæ.

Families: *Desmidioidæ*, *Spirogyraceæ*, *Zygnemaceæ*, *Mougeotiaceæ*.

This is a very sharply characterized alliance of Green Algæ. It is indeed difficult to determine its affinities. The forms belonging to it are especially characterized by never forming zoospores, and by possessing *aplanogametes*, i.e. gametes which, instead of escaping from the mother-cell and swarming freely, never leave the cavities of the cells in which they are produced. When conjugation is about to occur the two cells (gametangia), the contents of which will form gametes, approach one another, and their walls come into contact, either directly, or by the putting out from one or both cells of a short cellulose tube. The area of wall at the place of contact breaks down, and the whole or part of the contents of each cell then fuses with the corresponding protoplasm of the other to form a zygote.

The chromatophores of the Conjugatæ, though very various in the different families, are all very different from the types met with among the other Green Algæ.

I. *Desmidioidæ*. Cell-contents and outline symmetrically arranged on each side of a given median plane which is often coincident with a more or less deep constriction. Often unicellular.

II. *Zygnemoidæ*. Cells cylindrical, without median constriction, always forming threads.

1. *Spirogyraceæ*. Chromatophores one or more, parietal, spiral.
2. *Zygnemaceæ*. Chromatophores two, axile, roundish.
3. *Mougeotiaceæ*. Chromatophore single, axile, plate-like.

Desmidioides.—The Desmids are a large family of fresh-water forms numbering over a thousand species. Perhaps their most favourite habitat in this country is the water which collects and stands between mosses and similar plants on impervious soils. Many of the Desmids are among the most beautiful of algal forms.

The great characteristic of the Desmid-cell is its almost invariable division into two symmetrical halves, often separated by a circular constriction (cf. fig. 372). The cell-membrane usually consists in fact of two distinct valves whose edges meet in this median plane. In cell-division these two valves are forced apart, a new cylindrical piece of membrane being intercalated between them. A transverse wall

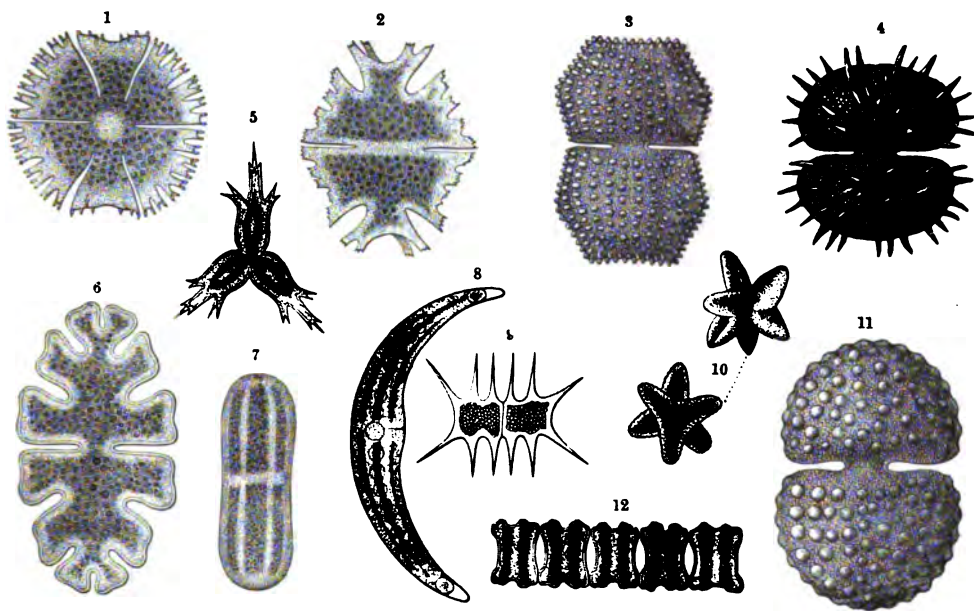


Fig. 372. Desmids.

¹ *Micrasterias papillifera*. ² *Micrasterias morea*. ³ *Cosmarium polygonum*. ⁴ *Xanthidium aculeatum*. ⁵ *Staurostrum furcatum*. ⁶ *Euastrum oblongum*. ⁷ *Penium Brebissonii*. ⁸ *Closterium Lunula*. ⁹ *Xanthidium octocornis*. ¹⁰ *Staurostrum alternans* (two views). ¹¹ *Cosmarium tetraophthalmum*. ¹² *Aptogonium Desmidium*. All the figures magnified about 200 times.

is then formed at the equator, and each half of the new piece of wall gradually assumes the characters of the old half-cell to which it belongs.

The actual form of the cell is very various; it is often lobed, and its wall sculptured in various ways. A good idea of the shapes of some of the commoner types can be obtained by an inspection of fig. 372; see also Plate I., i, k.

The chromatophores are also extremely various in form. A common type is an axile rod bearing longitudinal plates which radiate in all directions. Each chromatophore contains one or more pyrenoids.

The cell-membrane is usually perforated by series of regularly arranged, very minute pores which give exit to extremely delicate filaments of protoplasm. The projecting end of each filament is surrounded by a mass of mucilage, and these masses together form a complete sheath covering the entire cell, and sometimes even

groups of cells (*cf.* similar phenomenon in Diatoms, p. 626). Many Desmids possess the power of locomotion. Their movement is slow and creeping, and although the means by which it is brought about are by no means fully understood, it has been shown to have a connection with the excretion of mucilage, and to stand in relation with light and gravitation. Some forms (e.g. *Closterium* and *Penium*, figs. 372^s and 372⁷) have a curious rotating movement, one end being temporarily fixed while the other moves up towards the source of light.

Conjugation takes place as already described, the conjugating cells either coming into direct contact, or putting out short tubes. The conjoined tubes are known as the *conjugation-canal*. The zygote may be formed either in this or in one of the conjugating cells. The membrane of the zygote consists of three layers, the outer one being sculptured in various ways. In germination, the outer, sculptured membrane is burst open, and the protoplasm divides to form 2-8 cells which gradually take on the characters of the adult individual.

The cells of the thread-forming Desmids (*cf.* fig. 372¹²) possess all the characters of the unicellular types, the daughter cells simply remaining together after division (which always occurs in one plane) has taken place.

Spirogyraceæ.—This family contains the single genus *Spirogyra*, many species of which are amongst the commonest Algæ in our ponds and ditches. They form green or yellowish-green slimy masses on the mud at the bottom or floating at the surface of the water. Such a *Spirogyra*-mass usually contains several species, although the bulk of it is often formed by one.

The cells of the different species vary much in diameter, from the delicate *S. tenuissima* which is only about one hundredth of a millimetre across, to *S. crassa*, which forms coarse threads as much as one seventh of a millimetre thick. Roughly speaking, the broader the cell, the greater number of chromatophores it possesses. The smaller species possess only one spiral band in each cell (Plate I., 1), the largest as many as eight or nine.

Each *Spirogyra*-cell is a cylinder, in most cases considerably longer than it is broad (though the relation of length to breadth is variable even in one and the same species), with a very delicate layer of protoplasm lining the wall, and a large central vacuole. Each chromatophore forms a band embedded in the protoplasm, and twisting spirally round and round the cell at an approximately constant angle. When there are more bands than one they cross each other at regular intervals, forming a beautiful lattice-work. In some species each band makes several complete turns in its course down the cell (fig. 373); in others, it may be inclined at such a small angle with the long axis that it makes less than a complete turn in the length of the cell. In *S. orthospira* the bands are practically parallel with the long axis, so that they do not follow a spiral course at all, but form straight bands. Each chromatophore may be isodiametric, or, on the other hand, it may form a flattened band. In the latter case its edges are usually irregularly scalloped. A single row of pyrenoids at larger or smaller intervals is found in each chromatophore.

Each cell contains a single nucleus which occupies approximately the centre of the cell. In the larger species it is suspended in the middle of the vacuole by a number of branching threads, many of which run into the peripheral protoplasm opposite a pyrenoid. This can be particularly well seen in the large *S. crassa*. It suggests that the nucleus plays some active part in the function of starch formation. In the smaller species when the breadth of the cell is perhaps not more than double the diameter of the nucleus, the latter often lies in the concavity of, and in contact with, a chromatophore. In this case the protoplasmic threads are not so obvious.

All the cells of a *Spirogyra*-thread are capable of division. After the nucleus has divided, a rim of cellulose is secreted in the equatorial plane of the cell. This is gradually added to from within, till a complete disc of cellulose is formed, separating the two daughter-cells. Curious folds are always formed on the transverse walls of some species. Each fold forms a circular rim near the periphery of the transverse wall and projecting into the cell cavity. These folds are sometimes completely evaginated, the transverse wall thus having its surface considerably increased and becoming strongly concave towards the cell-cavity. This happens especially when two cells are separating from one another, or, when a gamete is formed from a neighbouring cell.

Multiplication is often effected by the breaking up of a filament into segments consisting of a few cells each which go on dividing and form a new thread.

Conjugation takes place in two ways; a zygote being produced either from gametes formed in two neighbouring cells of the same filament, or in two cells belonging to distinct filaments. In the former case a small swelling is formed opposite a septum, a small area of the septum breaks down, and the contents of one cell, rounding itself off from the walls, passes through the aperture thus formed and fuses with the contents of the other cell, also rounded off, to form a zygote, which immediately puts on a membrane, and enters upon a resting stage.

In the second or "ladder-type" of conjugation (fig. 373, and Plate I, 1), two filaments come to lie side by side, and the contents of some or all of the cells of one thread round off, each cell-wall growing out into a short tube towards a cell of the other thread. Each cell of the other thread then either swells up towards this tube or puts out a similar tube, and the walls coming into contact are absorbed, an open canal (conjugation-canal) thus being formed between the two cells. The contents of the first cell then passes through the canal into the cavity of the second, the contents of which has also rounded off, and fusion occurs between the two gametes. The whole of the cells of two filaments frequently conjugate about the

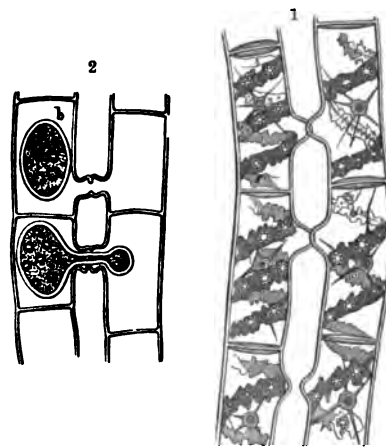


Fig. 373.—*Spirogyra*.

1 Two filaments commencing to conjugate.
2 Formation of zygotes.

same time, and the series of conjugation-canals thus formed give the appearance of the rungs of a ladder. All the zygotes are formed in one filament, which we may consider as physiologically female, its gametes being relatively passive compared with those of the other (male), which initiate the process, and actively pass through the canals. The relative behaviour of the two threads shows that an influence is exerted by the male on the female cell, the former determining the outgrowth and direction of the tube belonging to the latter, as well as the rounding off of the female gamete. If the female tube is not put out opposite the male, the former bends round to meet the latter, and if the male cell dies in the middle of the process, the female tube goes on growing indefinitely, and the female gamete does not round itself off. The influence exerted is in all probability a chemical influence, a phenomenon which seems to occur in connection with the process of the conjugation of gametes throughout the vegetable kingdom (*cf.* the remarks on pp. 68 and 413).

The chromatophore of the germinating zygote is formed from that of the female gamete alone, the band belonging to the male gamete gradually disintegrating in the zygote. This is an interesting example of the reduction of the specially vegetative portion of the male cell.

Zygnemaceæ.—The cell of *Zygnema* differs from that of *Spirogyra* (Plate I, m) in its remarkable and beautiful star-shaped chromatophores. There are two of these in each cell, occupying positions equidistant from the centre of the cell. Each possesses a rounded central portion, containing a single pyrenoid, from which thicker or thinner processes radiate in all directions. The nucleus forms a bridge between the two chromatophores.

Conjugation takes place much as in *Spirogyra*, the zygote being formed either in the conjugation-canal or in one of the conjugating cells.

Mougeotiaceæ.—This family is characterized by the possession of single axile plate-like chromatophores, and by the fact that part of the protoplasm of a conjugating cell does not enter into the formation of the zygote.

The chromatophore, which possesses a single row of pyrenoids, can alter its position according to the strength of the light to which it is exposed. In moderate light the plane of its surface is at right angles to the line of the incident rays, in stronger light it places itself in the same plane as these rays, so that they only fall upon its edge. In very strong light it contracts to form an irregular body in the centre of the cell.

In conjugation the cells of two threads either put out tubes, and form spherical zygotes in the conjugation-canals (*Mesocarpus*-type), or the two cells bend towards one another, and form a four-sided zygote, one side of which occupies the centre of each cell. The wall of the zygote thus cuts off the two ends of the two cell cavities, so that the zygote appears as if it were surrounded by four empty cells (*Staurospermum*-type). These, however, soon break off.

Gonatonema forms so-called aplanospores in the following way. A cell increases to double its former length, its contents (chromatophore, &c.) dividing into two parts. A swelling is formed in the middle of the cell, into which the two chromato-

phores and the bulk of the protoplasm move from each end. A wall is now formed round the contents of this swelling. Although the behaviour of the nucleus has not been followed, this certainly suggests a reduced process of conjugation, each half of the cell representing a gamete.

Mougeotiopsis is a genus whose chromatophore possesses no pyrenoids.

Alliance X.—Charales.

Family: *Characeæ*, the Stoneworts.

Are green submerged plants with segmented axes bearing whorls of leaf-like appendages at the nodes, upon which the antheridia and oogonia are borne. The antheridia are spherical and contain a large number of filaments, each cell of which produces a spermatozoid with two long cilia. The oogonium consists of an egg-cell inclosed in five spirally-twisted, tubular cells; on germination the egg-cell gives rise to a simple segmented filament (the pro-embryo) from which the adult form arises as a lateral bud. There are no swarm-spores. Vegetative propagation is by bulbils, detached branches, &c. This alliance, though placed here in sequence with the other alliances of Green Algæ, is probably remote from them in actual affinity. The Charales form an isolated and anomalous group, and various views are entertained as to their true position.

Members of this group occur very commonly in ditches, ponds, &c., and in brackish water. In the Norfolk Broads very extensive growths of these plants occur in the muddy bottom of the Broads, the living plants resting on the decomposing remnants of former generations; in this way the bottom level is being gradually raised.

Chara fragilis (see fig. 374) is perhaps the commonest species of the group, and is cosmopolitan in its distribution. The plant is some 12 inches high, and consists of axis with whorled leaf-like appendages inserted at the nodes. The axis consists of a number of long cells (the internodal cells) with which alternate the short nodal cells. The former remain undivided, whilst the latter originate the appendages and also a number of tubes, which, growing both upwards and downwards, everywhere cover in the internodal cells, forming a sort of cortex. The "leaves" have a structure essentially similar to that of the stem; they are, however, of limited growth (fig. 374³). They bear at their nodes tiny leaflets and the reproductive organs. The oogonia and antheridia occur together in this species (figs. 374² and 374³), the latter below the former. The antheridia are spherical orange-coloured bodies, consisting of eight shields or plates whose edges dovetail into one another; each bears a process (the manubrium) on its inner surface, and each of these manubria bears a tuft of filaments (fig. 374⁵), in every cell of which a coiled spermatozoid is produced bearing 2 long cilia at the tip (figs. 374⁶ and 374⁷). The shields now disarticulate and the spermatozooids escape. The oogonia (or amphigonia) remotely resemble the archegonia of Ferns (*cf.* fig. 346², p. 472). Each contains a big oval egg-cell inclosed in a sheath of 5 tubes spirally wound around it. The tips of these tubes

form a crown surmounting the oogonium (fig. 374⁸). At fertilization the spermatozooids penetrate between the cells of the crown, so reaching the egg-cell. The whole oogonium is soon detached and remains dormant through the winter. In the spring it germinates, pushing out a tube which becomes transversely segmented. This is the pro-embryo. From it, as a lateral bud, the adult sexual plant arises. This process resembles that of the Mosses, in which the leafy Moss-plant arises from

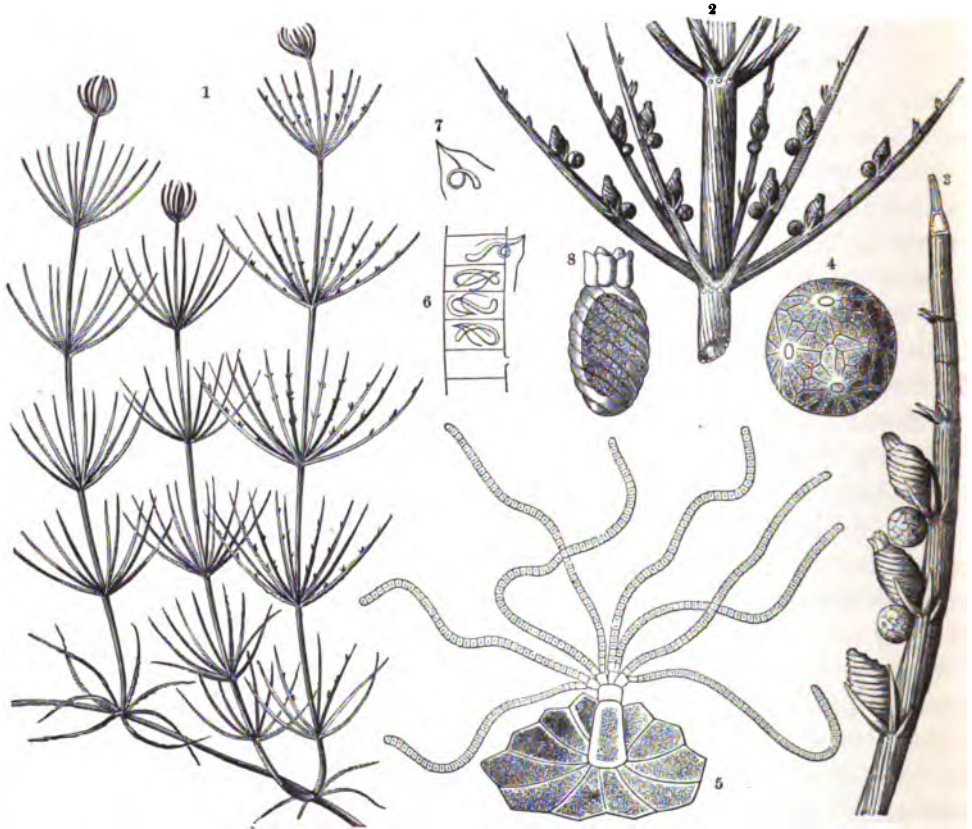


Fig. 374.—Structure and reproduction of *Chara fragilis*.

¹ A portion of the plant. ² A piece of the axis with appendages, upon which are inserted the sexual organs. ³ A single appendage, showing the flask-shaped archegonia and spherical antheridia. ⁴ A single antheridium. ⁵ A plate of an antheridium with manubrium and whip-like filaments of cells containing spermatozooids. ⁶ Several cells from one of the whip-like filaments: the cells in the middle contain each a spermatozooid; the spermatozooid is escaping from the uppermost cell; the lowest cell is already vacated. ⁷ A single spermatozooid. ⁸ Archegonium inclosing the egg-cell. ¹ nat. size; ² $\times 10$; ³ $\times 15$; ⁴ $\times 25$; ⁵ $\times 100$; ⁶ $\times 300$; ⁷ $\times 500$; ⁸ $\times 50$.

the protonema as a lateral bud. But the comparison with Mosses must not be pushed too far, as in *Chara* there is no sporogonium. There are some 67 species of *Chara*, of which *C. fetida* is also very common. Many of them are covered with stiff hairs, and they are for the most part brittle owing to the incrustation of carbonate of lime (cf. vol. i. p. 260). The phenomenon of parthenogenesis in *Chara crinita* has already been described in detail (pp. 463, 464).

In *Chara stelligera* (= *Tolypellopsis ulvoides*) the nodes of the stem become

swelled out with starch, and assume a stellate form (starch-stars). They serve as organs of vegetative propagation.

The other large genus of Characeæ is *Nitella*. It is especially distinguished by the fact of its stems and leaves being destitute of cortex. There are 67 species of *Chara* and 77 of *Nitella*.

Characeous fruits (*Gyrogonites*) are met with in large numbers in the lower chalk and in tertiary formations. Only rarely are fragments of the stems, &c., recognized.

Alliance XI.—Phæophyceæ.

Families: *Ectocarpaceæ*, *Sphacilariaceæ*, *Cutleriaceæ*, *Laminariaceæ*, *Fucaceæ*.

Includes the whole series of the Brown Sea-weeds, essentially characterized by the fact that their chlorophyll-corpuscles include, in addition to chlorophyll, a brown pigment, Phycophæin, which masks the green colour of the chlorophyll. The forms included under this alliance are all multicellular, and range from simple threads of cells to large complex forms showing a differentiation into a root-like attachment-organ, stipe, and expanded leaf-like frond. In several of these larger forms the internal structure almost rivals that of Flowering Plants in complexity. Within the limits of the group we find sexual reproduction, in some cases by the fusion of equivalent motile gametes (*cf.* p. 50), in others of well-marked egg-cells or spermatozooids. Fertilization and the complete life-history has been studied in relatively few cases.

Ectocarpaceæ.—These are mostly filamentous and often branched. Attached to the branches are the sporangia and gametangia. From the former motile zoospores are liberated. From the latter similar bodies—the gametes—are liberated. These possess two cilia, attached *laterally* to the gametes. The process of fertilization has been followed in *Ectocarpus siliculosus*. Certain of the gametes come to rest first, and these are approached by a number of other gametes, which swarm around them. Ultimately one of the swarming gametes fuses with the resting gamete and fertilizes it. This process has been thought to indicate the existence of a certain sexual differentiation amongst the gametes, the gamete which comes to rest first being the egg-cell. However, there is no demonstrable structural difference between them.

Sphacelariaceæ.—The filaments consist of many layers of cells. Reproductive organs agreeing in the main with the last-named family.

Cutleriaceæ.—Mostly branched, ribbon-like forms. The gametangia are arranged in tufts, and the gametes differ in size, but both possess two cilia.

Laminariaceæ.—Perhaps the most interesting family of the alliance. Many forms are known to liberate motile reproductive cells from various portions of their surface, but the fate of these bodies has not been ascertained. They are large marine forms, some of them attaining gigantic dimensions. *Laminaria digitata*, which grows in quantities near low-water mark on our coasts (where it forms a regular "Laminaria-zone"), has a tuft of powerful roots holding it to the rocks, a long

stipe, and a flat, expanded leaf, deeply lobed like a hand. It is often met with two metres in length. The leaf is of a leathery consistency, and the flattened or cylindrical stalk has a wide parenchymatous cortex and central "medulla", in which run curious tubes (the "trumpet hyphæ") which swell out at intervals, the swelling being traversed in a transverse direction by a delicate sieve-plate. The stem possesses a peripheral cambium-like zone, which adds each year a new zone of tissue to the cortex. The stems, which are sometimes found much thicker than one's

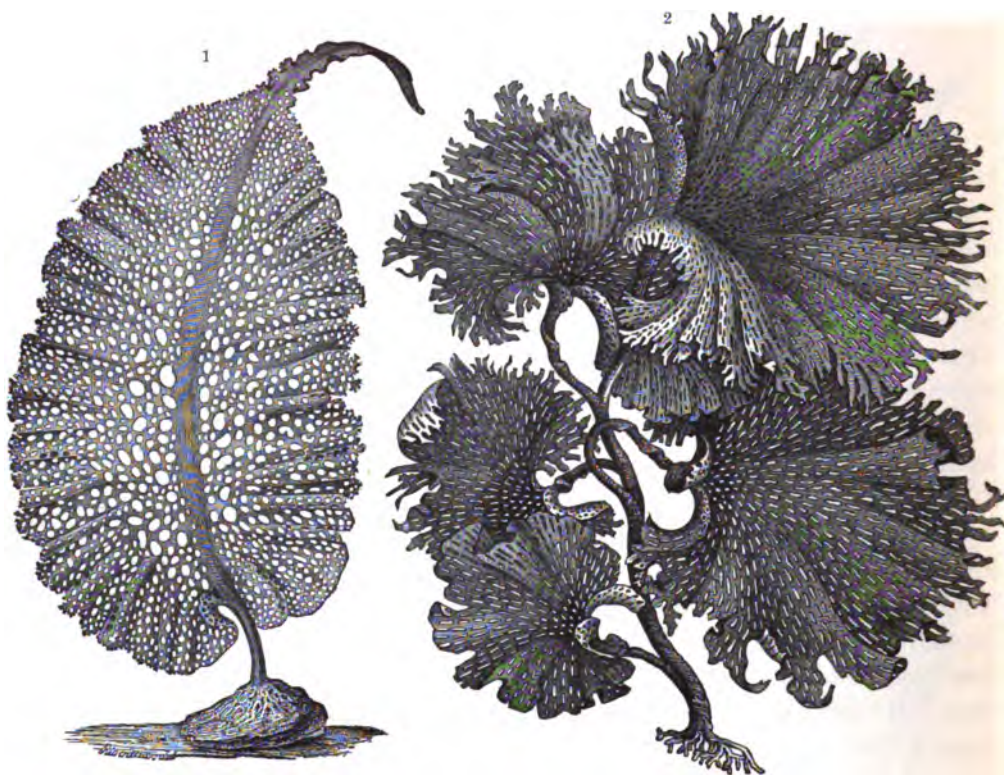


Fig. 375.—Laminariaceæ, with perforated fronds.

¹ *Agarum Gmelini* (after Biocreux). ² *Thallasiophyllum clathrum* (after Postels and Enprecht). Both much reduced.

thumb, show in section a series of rings, reminding one of the annual rings of a dicotyledonous stem. A long ribbon-like form, *L. saccharina*, is also common on our shores. In other forms the frond is branched and often curiously appendaged at the base. In the two genera represented in the accompanying illustration (figs. 375¹ and 375²) *Agarum* (from the North Atlantic) has a simple, *Thallasiophyllum* (North Pacific) a compound frond. In both the fronds are perforated or fenestrated. *Lessonia* (Southern Pacific) attains to tree-like dimensions and is much branched; it has a stem as thick as a man's thigh. But the two most impressive genera are *Macrocystis* and *Nereocystis*. The former, which occurs throughout the southern oceans and on the western coast of N. America, consists of a long stalk, sometimes attaining a length of 300 metres, but in thickness not exceeding a penholder. To

this stalk are attached a series of long ribbon-like leaves, each of which, just at its point of insertion upon the stem, swells into an air-bladder about the size of a pigeon's egg. Thus the stem, which is attached below, is buoyed up, and the long leaves depend into the water. In structure the stem is not unlike that of a *Laminaria*; but it possesses in addition to the medulla, with its trumpet hyphæ, a zone containing large sieve-tubes, which resemble those contained in the soft bast of a Flowering Plant (cf. vol. i. fig. 10⁴, p. 45, and fig. 125⁷, p. 469).

Nereocystis, occurring on the W. coast of N. America, consists of a long stalk (attaining to a length of nearly 100 metres), attached at its lower extremity and expanding above into a huge retort-shaped air-sac, from the surface of which a number of fronds (6-10 metres in length) arise. Like *Macrocystis*, its stem contains well-marked sieve-tubes. It is used by the Aleutians as fishing-line. Of *Laminariaceæ* about

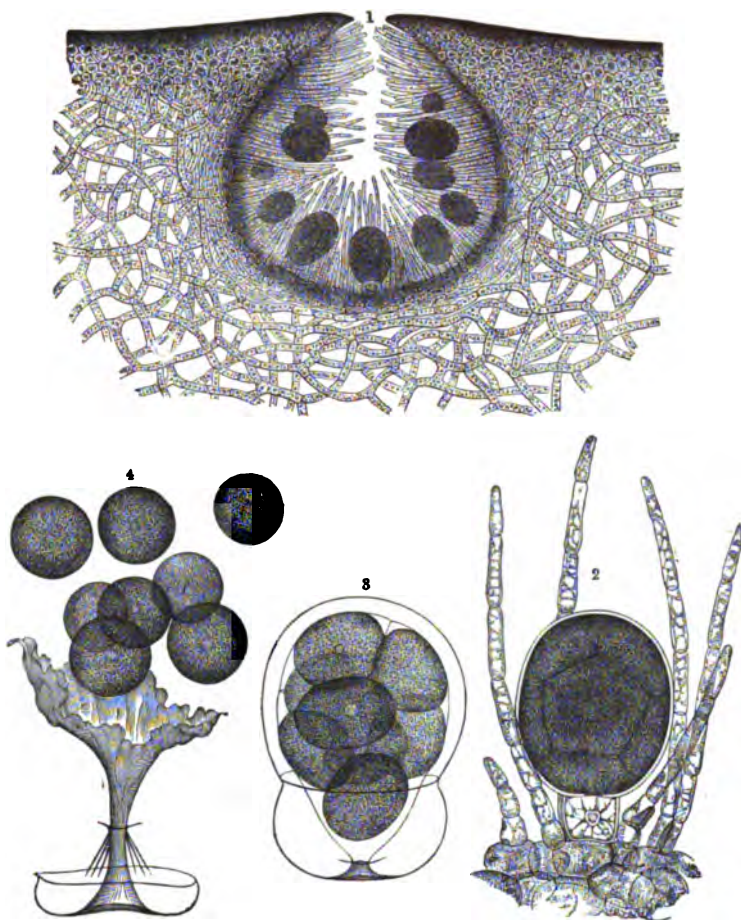


Fig. 376.—*Fucus vesiculosus*.

¹ Vertical section through a female conceptacle. ² A single oogonium from the conceptacle surrounded by sterile hairs. ³ A detached oogonium containing 8 egg-cells; the inner lamella of the wall is much swollen. ⁴ Liberation of the egg-cells. ¹×50; ^{2,3,4}×100. (After Thuret.)

90 species have been distinguished (including 30 species of *Laminaria*).

Fucaceæ.—Includes a number of the larger common sea-weeds. They are characterized—like the last family—by a segmentation into a well-marked shoot and organ of attachment. The former is usually flattened and branched, and often bears air-bladders. Reproduction is by means of spermatozoids and non-ciliated egg-cells, which arise in flask-shaped hollows (conceptacles) on definite portions of the shoot or frond. Asexual reproduction by detachment of fragments.

The Wrack-genus *Fucus* forms an exceedingly conspicuous feature of our sea-shore flora. The shoot is flattened and ribbon-like, branching in one plane and attached to stones, &c., by a sucker-like disc. In many species there is a midrib, as also air-bladders. The tips of many of the branches are studded with little rugosities

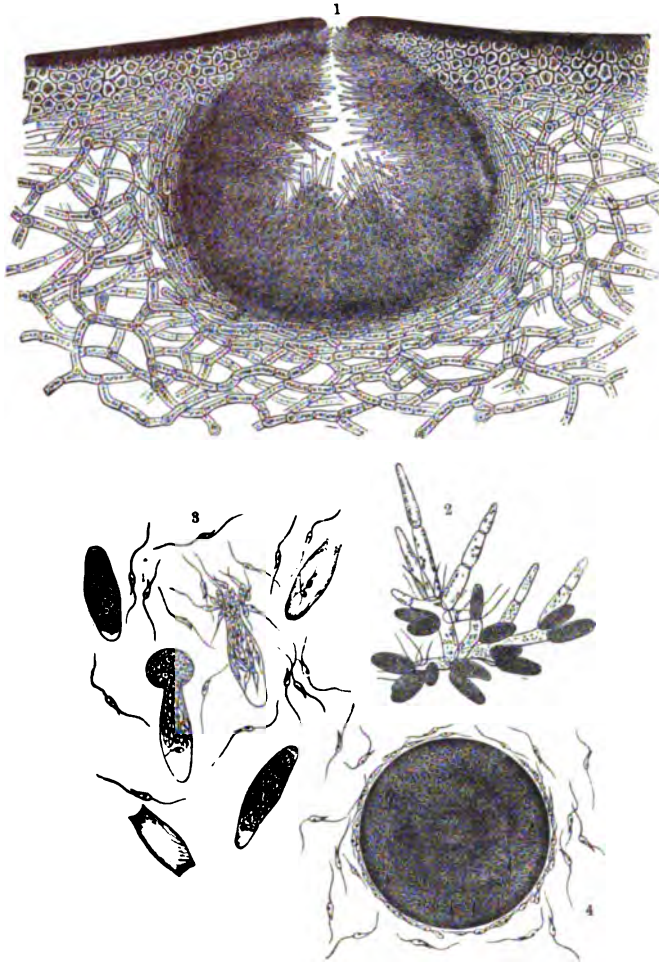


Fig. 377.—*Fucus vesiculosus*.

1 Vertical section through a male conceptacle. 2 A portion of one of the shrubby, branched hairs bearing antheridia. 3 Spermatozoids escaping from the antheridia. 4 Spherical egg-cell with spermatozoids attached. 1 \times 50; 2 \times 160; 3, 4 \times 350. (After Thuret.)

ties—really indicating the presence of pear-shaped hollows, the conceptacles. From the lining of these conceptacles project the oogonia and branched filaments bearing antheridia respectively. As a rule the male and female organs occur on distinct plants, though in some species the antheridia and oogonia occur side by side in the same conceptacle. The structure of the sexual cells and the act of fertilization (which occurs outside the mouth of the conceptacle) have been fully described on pp. 51, 52; they are represented in figs. 376 and 377. Sixteen species of *Fucus* are distinguished, and they occur for the most part in the seas of the northern hemisphere. *Fucus vesiculosus* and *F. serratus* are the commonest. Several other genera are represented

in Britain, *Pelvetia*, *Ascophyllum*, *Cystoseira*, *Halidrys*, and *Himanthalia*. The last-named genus is altogether peculiar, and consists of a top-shaped body attached by its pointed end, whilst from the upper surface of the "top" arise several ribbon-like outgrowths which branch repeatedly and attain to a length of several metres. It is upon these ribbons that the conceptacles are borne. Of exotic forms a few may be mentioned. *Durvillaea* from the southern seas resembles a thick, fleshy *Laminaria* in habit; from the summit of its thick stipe arise a

number of irregular fleshy lobes, which are produced into branching, whip-like filaments. Its tissues possess a curious honey-combed structure. It is stated that in Chili, &c., *D. utilis* is used as an article of food. *Sargassum* is distinguished by its high differentiation. It has cylindrical stalks bearing leaf-like appendages, and little stalked spherical air-bladders, and receptacles for the sexual organs. Some 150 species of this very varied genus are known, scattered over the warmer zones of the world. Particular interest attaches to the Gulf-weed (*Sargassum bacciferum*, fig. 378) which forms the chief component of the floating masses of *Sargassum* in certain regions of the Atlantic.

The Sargasso Sea has received its name from the enormous amounts of this floating weed which are met with there. It occupies an area in the Atlantic perhaps equal to that of the continent of Europe. There are two main accumulations, the larger south-west of the Azores, the smaller situated between the Bermudas and Bahamas, whilst connecting them is a narrow belt. The exact nature of these accumulations is not ascertained. According to one view the Gulf-weed actually lives a pelagic life, growing and multiplying in this huge eddy in mid-ocean, and is thoroughly adapted to its special environment; whilst, on the contending hypothesis, the vegetation of the Sargasso Sea is purely ephemeral, does not reproduce, and is constantly renewed by ocean currents, which bring with them countless fragments forcibly torn by tempests from the shores of Florida and the Bahamas. It is further alleged that the floating Gulf-weed is met with only in a condition more or less unhealthy (moribund) and in various states of decomposition.

The weak point in the latter hypothesis is the lack of convincing evidence to show that *S. bacciferum* grows attached in the region of the West Indies, &c., in quantity sufficient to supply the Sargasso Sea. Of another species, *S. vulgare*, there is plenty, but this is not the prominent constituent of the Sargasso Sea—indeed a trained algologist, in passing recently through this sea, examined samples amounting to more than a ton, but it was only *S. bacciferum* he found. Here, evidently, is still matter for the leisured naturalist.

Over 300 species of Fucaceæ (including 150 *Sargassums*) have been distinguished.



Fig. 378.—A branch of the Gulf-weed, *Sargassum bacciferum*, with leaves and air-sacs.

Alliance XII.—Dictyotales.

Family: *Dictyotaceæ*.

A small group of Brown Sea-weeds distinguished by the fact that both egg-cells and spermatozoids are destitute of cilia. The sexual cells are contained in club-shaped vesicles, inserted in tufts on the surface of the plants. Asexual reproductive cells ("tetraspores") are formed in sporangia in fours. They include the common *Dictyota dichotoma* and the beautiful iridescent fan-like *Padina pavonia*.

Alliance XIII.—Floridææ, Red Sea-weeds.

Aquatic, for the most part marine, plants, which contain in addition to chlorophyll, a red or purple pigment, *phyco-erythrin*; the pigment, as in the brown sea-weeds, is confined to definite corpuscles. Reproduction is by means of asexual spores (tetraspores), and sexually by non-ciliated spermatia and procarps.

With the exception of *Batrachospermum*, *Lemanea*, and one or two other genera, the Floridææ are marine organisms and inhabit on the whole a deeper zone than any other sea-weeds. Several views prevail as to the significance of the red pigment. As has been already indicated (vol. i. p. 390) the rays of light, useful in ordinary chlorophyll-assimilation, are soon absorbed, as white light traverses considerable strata of water. Such light as penetrates some distance from the surface is preponderatingly blue, and, as is now known, such rays are actually destructive of vegetable protoplasm. It may well be then that the red pigment serves to screen the protoplasm from the action of these rays, permitting the chlorophyll to make use of such of the red rays as filter to it; or—what is more probable—the red pigment is itself an assimilating pigment, either directly absorbing the blue rays and allowing the protoplasm of the chlorophyll-corpuscles to use their energy for building up complex food-materials, or indirectly (as indicated at vol. i. p. 390) by altering their wave-length they are made serviceable to the chlorophyll-corpuscles.

The Floridææ exhibit an enormous variety of form, and almost all of them are attached. There are the delicate cell-filaments of the *Callithamnions*, the corticated *Polysiphonias* and *Ceramiums* so common on our coasts, the fleshy cylindrical *Gracilarias* and *Polyides*, the flat and lobed *Chondrus* and *Gigartina*, the leathery *Iridæa*, and a host of others. One of the most beautiful of British genera is *Delesseria*, with its creeping stalk and crimson leaves with midribs and veins. In some species the leaves are entire, in others their margins are sinuous and lobed. Of all red sea-weeds perhaps the Australian *Claudea* holds the palm for beauty with its large latticed, rose-pink fronds. Certain groups, *Corallina*, *Melobesia*, *Lithothamnion*, &c., are encrusted with large amounts of carbonate of lime, and build regular banks and reefs under the sea. In all there are some 280 genera and 1800 species of Floridææ.

Reproduction by means of asexual spores is a common phenomenon in the group. These spores, though not invariably, are most frequently formed in clusters of four,

and are termed *tetraspores*. In the simpler forms they arise in little projecting sporangia, in other cases they are on specialized branches or embedded in the substance of the frond.

The sexual organs, however, are very remarkable, and differ from those of other Thallophytes. The male cells arise from clusters of cells (antheridia) at the tips of branches or in groups upon the surface of the frond. Each antheridium liberates a single, non-ciliated male cell termed a *spermatium*. The female organs or *procargs* consist of a filamentous receptive organ, the trichogyne, and a basal part, the *carpogonium* (cf. figs. 204⁷ and 204⁸, p. 53). Besides the carpogonium there are *auxiliary cells*, to be described directly. The process of fertilization has been followed in detail in *Nemalion* since the earlier portions of this volume passed through the press, and we now know that the suggestion of an osmotic fertilization in the Floridæ (cf. p. 60) is erroneous. The spermatium becomes attached to the trichogyne, and at this point the wall of the trichogyne is absorbed. The nucleus of the spermatium enters the trichogyne and travels down it to the carpogonium at the base, where it fuses with the carpogonial nucleus. The carpogonium now divides, giving rise to a mass of spores (the carpospores). In other cases the process is less simple. As before there is a trichogyne and carpogonial cell, but associated with the latter a number of auxiliary cells. The carpogonium when it is fertilized does not give rise at once to a mass of spores, but enters into a process of conjugation with these auxiliary cells, and from them the carpospores arise. This conjugation may be an immediate fusion, or may be brought about by the instrumentality of special tubes. Thus we may suppose the fertilizing influence to be transmitted. In some cases (as in *Dudresnaya*) this may take place over considerable distances, from branch to branch. In the simpler forms the procargs are modified branches projecting freely into the water; in the more fleshy and ribbon-like forms they are sunk in hollows on the thallus and often associated with a large number of auxiliary cells. The trichogyne projects into the water through a small pore in the portion of the surface which roofs over the procarp and auxiliary cells. As a result of fertilization of the carpogonium and its conjugation with the auxiliary cells, a large mass of carpospores arises, which raises up the surface like a blister.

Fossil remains of red sea-weeds occur under the name of Nullipores. These are the calcareous incrustations of the *Corallinas*, *Melobesias*, *Lithothamnions*, &c., mentioned above. They occur in both the secondary and tertiary rocks. The Leitha limestone, largely used for building purposes in Vienna, comes from extensive nullipore banks in the Leitha Mountains, south-west of Vienna on the Hungarian frontier, and, just as in Paris many of the finest buildings are constructed of the consolidated calcareous remains of Foraminiferæ, so in Vienna are the incrustations of certain red sea-weeds put to this purpose.

Class V.—FUNGI.

Parasitic or saprophytic plants destitute of chlorophyll and for the most part possessing a mycelium. Sexual reproduction known and generally admitted in the Phycomycetes only. Asexual reproduction by means of spores and conidia.

Sub-class I.—PHYCOMYCETES.

Mycelium for most part unicellular, tubular, and branched. Sexual reproduction both by conjugation of equivalent cells and by egg-cells.

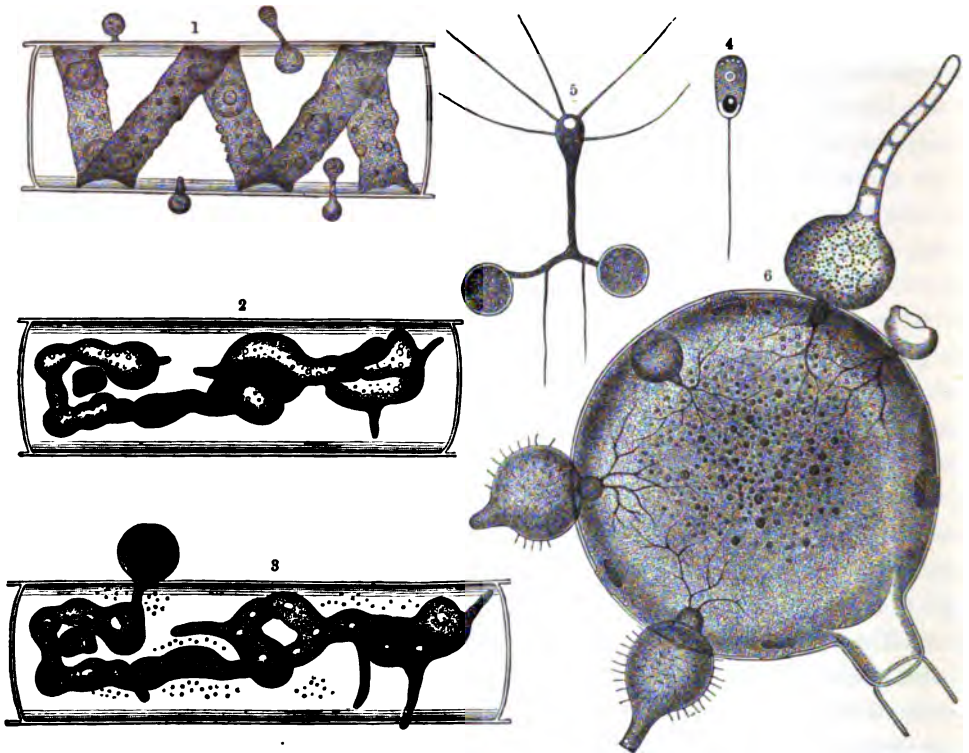


Fig. 379.—Chytridiaceae and Ancylistaceae.

1, 2, 3 *Lagenidium Rabenhorstii*, parasitic upon *Spirogyra*. 4, 5 *Polyphagus Euglena*. 6 *Rhizidiomycos apophysatus*, parasitic on an oogonium of *Saprolegnia*.

Alliance XIV.—Oomycetes

Families: *Peronosporaceae*, *Saprolegniaceae*, *Chytridiaceae*, *Ancylistaceae*, *Entomophthoraceae*.

Mycelium often very slightly developed; asexual reproduction by means of swarm-spores; sexual reproduction by egg-cells. On the whole in this group we are dealing with Fungi which very nearly resemble the Algae of the Alliance Siphonae (e.g. *Vaucheria*) both as regards the structure of their mycelium and mode of reproduction. A loss of sexuality is to be noted in many members of this group.

Peronosporæ.—Are mostly parasitic upon Flowering Plants, and the cause of many destructive diseases. They establish themselves by means of a branching, tubular, non-septate mycelium which penetrates the intercellular system of the host-plant (cf. p. 56). They propagate asexually by means of unicellular sporangia borne on branched hyphæ which project from the stomates, &c., of the host (cf. fig. 381²); these sporangia (or spores as they are sometimes termed) liberate on a moist substratum a number of swarm-spores (figs. 381^{4,5,6}) which originate new plants.

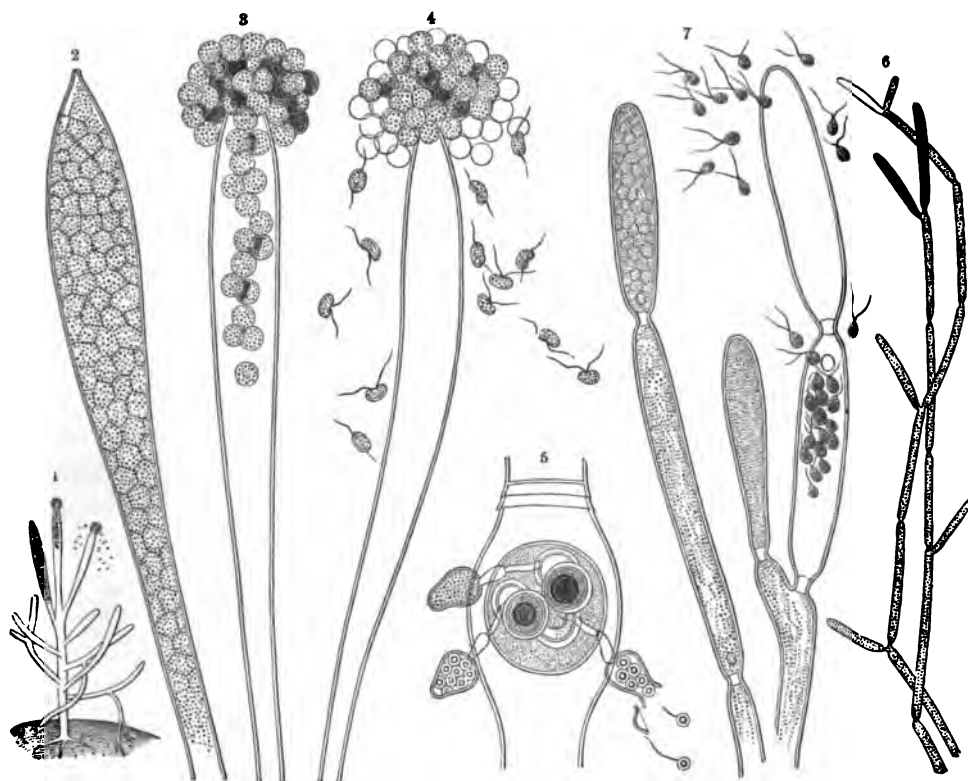


Fig. 380.—Swarm-spores in Saprolegniaceæ and Chytridiaceæ.

¹ *Achlya prolifera*. ^{2, 3, 4} Successive stages of swarm-spore-formation in *Achlya prolifera*. ⁵ *Chytridium Olla*, parasitic on the oogonium of the Alga *Kladoxium*; development of swarm-spores. ⁶ *Saprolegnia lactea*. ⁷ Development of swarm-spores in the same. (Partly after De Bary and Pringsheim.) ¹ $\times 20$; ^{2, 3, 4} $\times 400$; ⁵ $\times 800$; ⁶ $\times 100$; ⁷ $\times 800$.

Sexual reproduction also takes place by the formation of oogonia and tube-like antheridia. The latter become attached to the former (fig. 381³), and, putting out fertilizing tubes which penetrate to the egg-cell within the oogonium, transmit their spermatoplasm. No spermatozooids are differentiated, but the spermatoplasm travels *en masse*. The fertilized egg-cell enters on a resting stage, and when it germinates may either give rise to swarm-spores (e.g. *Cystopus*) or grow at once into a new plant (*Pythium*, *Peronospora*). To *Phytophthora infestans* is due the well-known Potato-disease. The Fungus attacks the foliage and reproduces abundantly asexually. Later, its mycelium penetrates to the tubers and passes into a dormant state there. Consequently when stored these potatoes go bad, and if

used for planting are liable to reproduce the disease next year. Sexual reproduction is as yet not certainly known to occur in the life-history of the Potato-disease Fungus. *Phytophthora omnivora* and *Pythium de Baryanum* attack and destroy many young seedlings, causing them to "damp off". Various species of *Peronospora* are known which attack large numbers of cultivated plants. *P. parasitica* works havoc amongst the Cruciferæ; *P. viticola* (= *Plasmopara viticola*, fig. 381) has been referred to as a deadly disease on the Vine; *P. Viciæ* on various leguminous

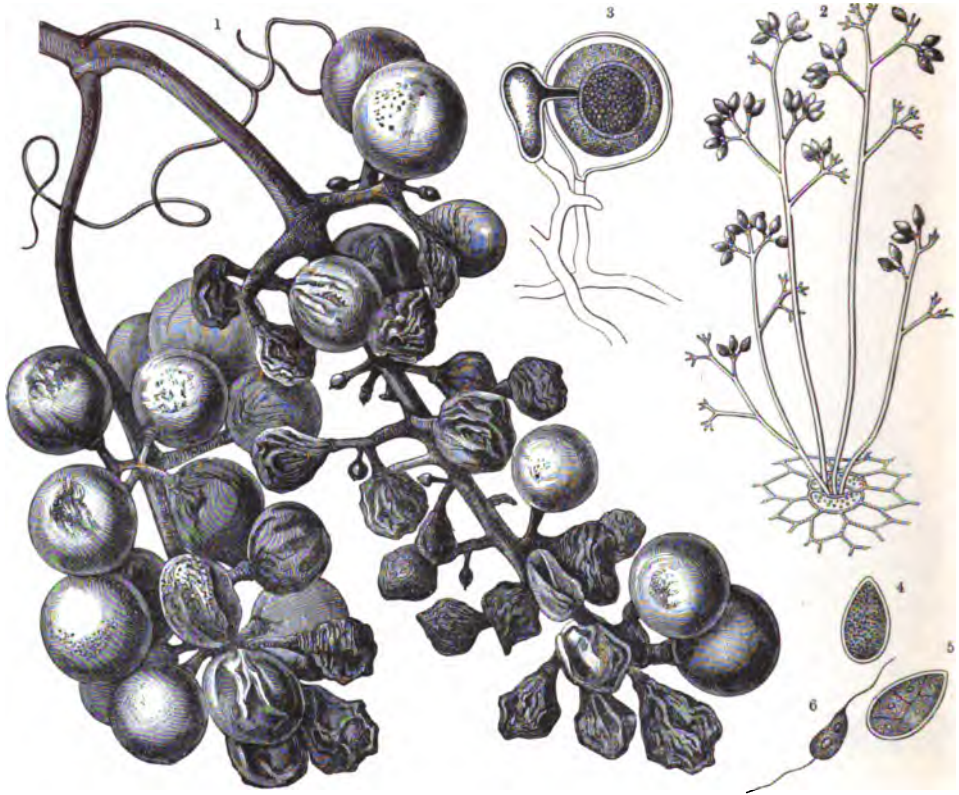


Fig. 381.—The False Vine-mildew, *Peronospora viticola*.

¹ A bunch of grapes attacked by the False Vine-mildew. ² Spores or conidia on branched hyphae projecting from a stoma of a Vine-leaf. ³ Fertilization. ⁴ A single conidium. ⁵ Swarm-spores arising within the conidium. ⁶ A single swarm-spore. ¹ nat. size; ² $\times 80$; ³⁻⁵ $\times 350$; ⁶ $\times 380$. (²⁻⁶ after De Bary.)

crops; *P. Hyoscyami* on Tobacco-plants, besides which there are many others. The effects of *Cystopus candidus* have already been mentioned (p. 525); it is common upon cruciferous plants.

About 100 species of *Peronosporæ* have been distinguished.

Saprolegniaceæ.—Are all aquatic and for the most part saprophytic; a few are parasitic on fish. In structure they much resemble *Peronosporæ*. Swarm-spores are liberated in large numbers from the enlarged ends of the hyphæ (fig. 380). Sexual organs arise much as in *Peronosporæ*, but although the antheridia develop fertilizing tubes in several instances, no case has been observed in which an actual transfer of spermatoplasm occurs. As a rule several or many egg-cells are produced

in the oogonia (fig. 382), and these germinate parthenogenetically. Although the sexual organs are still preserved in this group their function has been lost, leading the way to their complete atrophy in many other groups of Fungi. Many members of the group occur upon the bodies of dead insects and fish (e.g. various species of *Saprolegnia*, *Achlya*, *Aphanomyces*). *Aphanomyces phycophilus* is parasitic upon Algæ (e.g. *Spirogyra*) and *Saprolegnia* *Ferax* upon Salmon, &c.

About 45 species have been distinguished.

Chytridiaceæ.—Small parasitic aquatic Fungi whose mycelium is almost entirely wanting; they produce characteristic sporangia which liberate uniciliate swarm-spores. *Polyphagus Euglenæ* develops a very delicate mycelium, of which the branches become attached to *Euglena*-cells (fig. 379⁵, two *Euglenas* are thus attacked), and from the central portion of the mycelium arises a sporangium from which uniciliate swarm-spores (fig. 379⁴) are liberated. These in turn germinate, develop threads, and entangle fresh *Euglenas*. *Rhizidiomyces* attacks the oogonia of *Saprolegnias*, sending a branching mycelium into their interior (fig. 379⁶) and producing a pear-shaped sporangium at the surface which liberates numerous swarm-spores. *Chytridium Olla* (fig. 380⁵) produces its sporangia on the oogonia of *Edogonium*; its swarm-spores escape by the removal of a lid.

Over 180 species are known.

Ancylistaceæ.—Very nearly resemble the *Chytridiaceæ* in mode of life, but differ in exhibiting sexuality. *Lagenidium Rabenhorstii* attacks cells of *Spirogyra*, &c. The spores become attached to the *Spirogyra*-cells, and penetrate the wall (fig. 379¹) by means of a tube which branches about within, forming a lobed, irregular body (fig. 379²), which may open at the outside, liberating swarm-spores (fig. 379³), or sexual organs may arise inside and fertilization take place.

14 species have been distinguished.

Entomophthorææ.—A group of forms almost all of them parasitic on insects. They are adapted to non-aquatic life, and connect the Peronosporæ with the Zygomycetes.

The tubes of these parasites having effected an entrance into the body of an



Fig. 382.—*Achlya lignicola*.

¹ Oogonia with antheridia and fertilizing tubes; no fertilization happens, however. ² An oogonium containing egg-cells which have put on cell-walls without being fertilized. ¹ and ² $\times 400$. (After Sachs.)

insect, bud and sprout there with great activity. *Entomophthora radicans* commonly attacks caterpillars of the Cabbage-white (*Pieris Brassicæ*). Having spread through its interior, it sends out tufts of hyphæ on the ventral side (fig. 383¹), thus rooting the caterpillar to the substratum. It now develops hyphæ all over the body wrapping up the caterpillar like a mummy (fig. 383²). At the tips of these hyphæ conidia are abstricted and shot off to some little distance (figs. 383^{3, 4, 5}). A con-

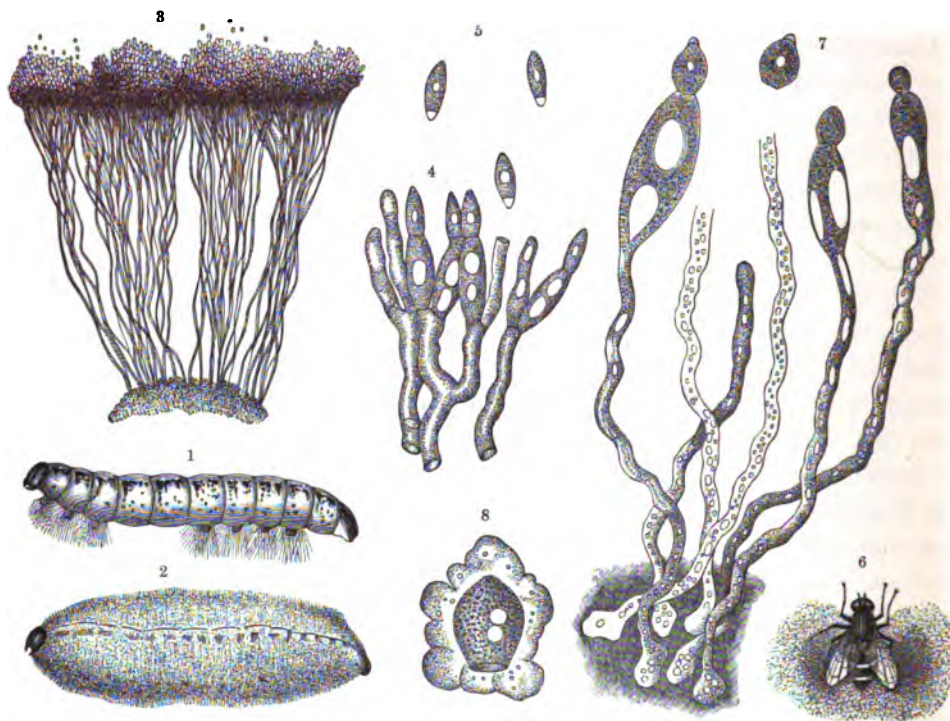


Fig. 383.—Entomophthoræ: *Entomophthora* and *Empusa*.

¹ A caterpillar of the Cabbage-white Butterfly attacked by *Entomophthora radicans*. ² The same caterpillar fully invested by the Fungus. ³ Tufts of conidia-bearing hyphæ from the back of the caterpillar. ⁴ Conidia separating from the tips of the hyphæ. ⁵ Disarticulated conidia. ⁶ A Fly attacked by *Empusa Muscæ*. ⁷ Hyphæ of *Empusa Muscæ*, from the tips of which conidia are being shot off. ⁸ Conidium inclosed in sticky mucilage. ^{1, 2, 6} nat. size; ^{3, 5, 7} $\times 80$; ^{4, 8} $\times 300$; ⁵ $\times 630$. (After Brefeld.)

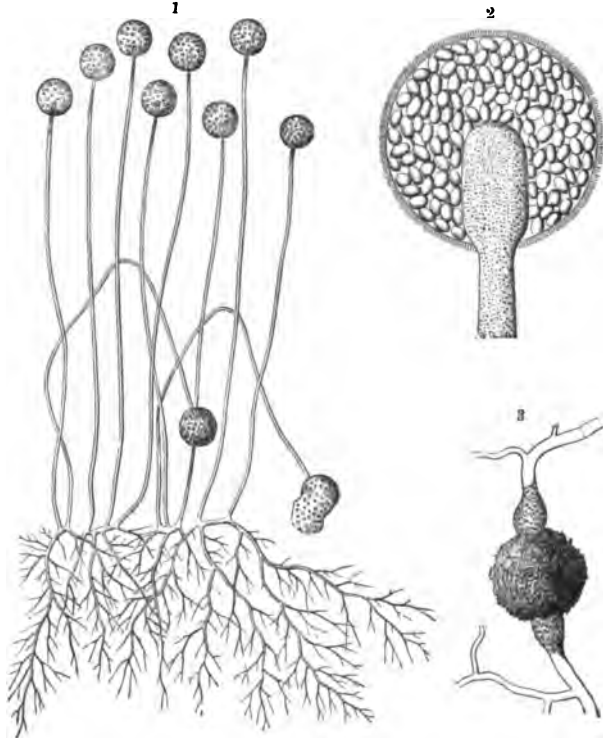
jugation of branches sometimes occurs, whilst in other cases fruits are formed parthenogenetically. *Empusa Muscæ* produces a disease common amongst flies in the autumn. The Fungus having effected an entrance into the body of a fly gradually fills it up with its sprouts. In due time tubes penetrate the surface and develop conidia at their extremities (fig. 383⁷). These are shot off as in the last case, and one may often see flies stuck to the window-pane in autumn surrounded by a halo of these conidia (fig. 383⁶).

About 80 species of Entomophthoræ are known.

Alliance XV.—Zygomycetes.

Families: *Mucoraceæ*, *Mortierelleæ*.

Are mould-like saprophytes with a much-branched, non-septate mycelium, sexual reproduction by conjugation; swarm-spores never met with. The common *Mucor Mucedo* (fig. 384) may be regarded as typical of this group. Its mycelium establishes itself on the substratum, and develops long-stalked sporangia at various points on its surface (fig. 384¹). In each sporangium (fig. 384²) numerous spores are contained, and these can germinate, producing new mycelia on a suitable substratum. A conjugation of branches of the mycelium leading to the production of a fruit or zygospore (fig. 384³) occasionally takes place, but the sexual method of reproduction is much commoner in other members of the group (cf. pp. 53, 54). The zygospore (or zygote) is invested in a strongly thickened membrane and can remain dormant for a considerable period. The hyphæ in many of the *Mucors* can break up into continuous chains of cells which disarticulate and propagate the plant; these offshoots are known as chlamydospores or gemmæ.

Fig. 384.—*Mucor*.

¹ Mycelium with stalked sporangia; $\times 40$. ² A single sporangium; $\times 260$.
³ A zygospore produced by conjugation; $\times 160$.

It often happens amongst the *Mucors* that although the conjugating branches are produced, they do not conjugate but each produces a fruit parthenogenetically. These, in contradistinction to zygospores, are called "azygospores". Or, as in *Mucor tenuis*, the "conjugating branches" no longer arise in pairs but isolated; these also form azygospores. Thus in this group, as in the Saprolegniaceæ of the alliance Oomycetes, we note a tendency for sexuality to become obsolete (cf. p. 670). A good deal of variety exists in the *Mucoraceæ* in the arrangement of the sporangia. In *Thamnidium* the sporangial branch ends in a large sporangium, and in addition bears laterally a number of tiny sporangia (sporangioles) containing four spores each, whilst in *Chaetocladium* there is a further reduction, and the sporangioles contain

but a single spore. Whilst the bulk of Mucoraceæ are saprophytes on animal excreta, &c., a certain number are parasitic on Mucor itself as well as other Fungi.

The *Mortierelleæ*, though in general resembling Mucoraceæ, are distinguished by the fact that their zygospores become invested in a plexus of mycelial hyphæ which form a sort of pericarp around the fruit. The base of the sporangial hypha also is invested in a sort of bird's-nest. This condition is of interest as it leads on to the more complex fruits of higher Fungi.

The Zygomycetes include 125 species.

Sub-Class II.—MESOMYCETES.

Mycelium multicellular; asexual reproduction alone is known by means of spores (not limited in number) developed in sporangia; or by conidia. They are regarded as occupying an intermediate position between the lower Fungi and the two large groups of higher Fungi, the Ascomycetes and Basidiomycetes respectively.

Alliance XVI.—Hemiasci.

Tube-like sporangia containing an unlimited number of spores. This alliance leads on to the Ascomycetes.

Families: *Ascoideæ*, *Protomycetes*, *Theleboleæ*.

These are mostly simple forms of parasites characterized by the indefinite number of spores contained in their sporangia. Some of them produce chlamydo-spores freely. *Thelebolus* is interesting in that its sporangium is inclosed in a cortex and may be compared with *Mortierella* of the Zygomycetes on the one hand, and with the corticated Ascomycetes (carpo-asci) on the other.

There are about 20 species belonging to this alliance.

Alliance XVII.—Hemibasidii.

Parasites with a septate mycelium, which forms numerous chlamydospores. From these spores a promycelium is developed on which conidia (sporidia) are produced. No sporangia are formed. This alliance is thought to lead on to the Basidiomycetes.

Families: *Ustilaginaceæ*, *Tilletiaceæ*.

These are all parasitic forms, and are known as the Smuts. The mycelium grows in the living tissues of the host, and concludes its development with the production of chains of chlamydospores (cf. p. 673), which are provided with a thick membrane, and are usually dark in colour. It is in respect of this character that the name "Smut" has been given. Very often these chlamydospores are produced in connection with the fruiting organs of the host-plant (various Grasses, &c.). The

chlamydospores only germinate after they have been distributed, and in a very characteristic manner. A short tube is formed, and from this (the promycelium or *basidium*, cf. p. 674) conidia (= sporidia) are abstricted. In the Ustilaginaceæ this basidium is septate and the conidia are abstricted *laterally*; in the Tilletiaceæ the basidium is non-septate, and the conidia are abstricted as a crown at the apex. This is the main difference between the two families. The conidia, which are budded off from the promycelium, have the power of budding in a suitable soil with enormous facility, forming new conidia, and this may be continued for a considerable time. In this way the soil becomes thoroughly infected, and should a young seedling host-plant arise, it is almost certain to be penetrated and invaded by one of these germ-like conidia.

Ustilaginaceæ.—These are the Smut-fungi properly speaking. *Ustilago segetum* (= *Ustilago carbo*), the common Smut of Wheat, Barley, Oats, &c., has been very fully investigated. The cereals in question become infected when quite young by the tiny conidia, which put out delicate germinal tubes and penetrate the young growing tissues. Should the young plants escape infection at this stage, they are safe against the parasite, which cannot penetrate the hard, adult tissues. The tubules of the *Ustilago* penetrate from cell to cell, and take up their position at the growing point. Here they keep pace with the growth of the host, but the presence of the parasite is not manifest externally until the grain begins to ripen. As the grains begin to swell, the fungus increases rapidly, and occupies the greater portion of their substance with its mycelium. It thrives, of course, at the expense of the food which would otherwise have served in forming the embryo and reserve of food-material in the seed. Finally, the Fungus resolves itself into masses of black chlamydospores—the “smut”—which appear between the glumes of the ear. These chlamydospores, as already stated, after a period of rest, produce their promycelia and bud off conidia, which in turn bud off other conidia, and so the ground is kept infected. It was formerly a matter of mystery how the Fungus got into the host-plant, as traces of it were not recognized till it burst out in the ripening ear in the “smut” stage. It is only comparatively recently that the period of infection has been recognized, and the fact that the mycelium grew up, so to speak, with the host-plants was fully realized. *Ustilago Maydis* produces hypertrophied growths on the Maize, and has been alluded to in a former chapter (cf. p. 524). *Ustilago violacea* attacks the stamens of many Caryophyllaceæ, developing its chlamydospores in place of pollen in the anthers. *Ustilago longissima* is very common in the leaves of the aquatic Grasses *Glyceria aquatica* and *G. fluitans*; it produces its chlamydospores as long, parallel, black lines.

More than 60 *Ustilagos* have been distinguished; a large number of them attack cereals and other grasses.

Tilletiaceæ.—Have on the whole a life-history resembling the Ustilaginæ; their main point of difference residing in the fact that the promycelium is unsegmented, and produces its conidia in a crown at the apex. *Tilletia Triticum* attacks wheat. In *Urocystis* the spores are clustered into little balls, the accessory spores forming a

sort of cortex around the central spore which germinates as in *Tilletia*. *Urocystis Violæ* is common on the leaf-stalks and blades of Violets.

About 100 species of Tilletiaceæ have been distinguished.

Sub-class III.—MYCOMYCETES.

Mycelium many-celled. Reproduction asexual, either by spores of limited number in asci, or by conidia of limited number on basidia.

Alliance XVIII.—Ascomycetes.

Parasitic (or saprophytic) Fungi, producing spores in special tubular sporangia, the *asci*. These spores, termed *ascospores*, do not exceed 8 in number. In addition to the asci there are subordinate conidial fructifications.

Families: *Exoascaceæ*, *Perisporiaceæ*, *Pyrenomycetes*, *Discomycetes*.

As stated, this alliance is characterized by the possession of sporangial fructifications, consisting of tubular asci containing as a rule 8 ascospores. A number of such asci are shown in fig. 388² with sterile supporting hyphæ, the paraphyses, between them. In addition to these ordinary and typical ascus-bearing fructifications, secondary fructifications producing conidia or chlamydospores are largely met with; consequently many of these Fungi appear under several forms in addition to the ascus stage. The Ascomycetes are divided into families according to the characters of the ascus-fruit. In the *Exoascaceæ* the asci are borne freely and exposed on the mycelium; in the other three families in special receptacles. In the *Perisporiaceæ* the group of asci is contained in a nut-like or tuber-like body; in the *Pyrenomycetes* the asci are produced in special pear-shaped excavations in a solid tissue which open by a pore to the exterior; in the *Discomycetes* the receptacle forms an open plate or cup, or sometimes an irregular body covered with the layer of asci.

Exoascaceæ.—This family comprises the parasitic genera *Exoascus* and *Taphrina*, the gall-like deformations caused by which were so fully described on pp. 524 and 527. The tissues of the host-plants are penetrated by the mycelia of these forms, and the asci are produced over the surface of the parts attacked, generally bursting through the cuticle of the epidermis. Each ascus contains 8 spores, but in many species many more than this number are often found; this is due to the fact that the 8 original ascospores begin to bud whilst still within the ascus, producing a large number of secondary spores (conidia). *Exoascus* has a perennial mycelium, and to its species are due a large number of the "witches'-brooms" and other hypertrophies. *E. Pruni* produces the "pocket-plum" (cf. p. 524); *E. Alni-incana* the curiously altered Alder catkins represented in fig. 358¹ (p. 523); *E. Carpini* the birds'-nest-like witches'-brooms of the Hornbeam; *E. deformans* the "curl" of Peach-leaves. *Taphrina* is largely a leaf-parasite, and its mycelium is not perennial. *T. carnea* causes blisters on the leaves of the Birch.

About 50 species of Exoascaceæ have been distinguished.

Perisporiaceæ.—Here are included all forms in which the asci are inclosed in fruit-like bodies, i.e. the Mildews, Moulds, and Truffles.

The Mildews are chiefly leaf-parasites, and spread their mycelium over the surface of the foliage and send their suckers (or haustoria) into the epidermal cells (cf. fig. 32², vol. i. p. 165). In due time they produce their ripe ascus-fruits like tiny black grains scattered over the surface of the leaf. Each of these fruits consists of a shell-like investment inclosing one or more asci, each of which contains 8 spores. *Sphærotheca* is the simplest form, there being but a single ascus in its fruit. *S. pannosa* is the Rose-mildew, and *S. Castagnei* the Hop-mildew, a very destructive parasite in Hop-growing districts. *Erysiphe* has several asci in its fruits, and includes the well-known *E. Tuckeri*, the true Mildew of the Vine (to be distinguished from *Peronospora viticola*, figured on p. 670, which is the false Mildew). A tropical genus of leaf-parasites allied to our Mildews is *Meliola*, which is widely distributed.

The Moulds include several exceedingly common saprophytes which make their appearance on the most various sorts of organic matter. The Blue Moulds, which occur on jam, bread, leather, &c., are probably the best known and most commonly recognized of all the smaller Fungi. These forms spread their mycelia over any suitable substratum, and penetrate it with their hyphæ. Their usual fructification is not the ascus-fruit, but clusters of conidia, borne on erect hyphæ, which stand out from the mycelium. Two common Moulds are represented in fig. 193, p. 18. *Aspergillus niger* (figs. 193⁴ and 193⁵) bears its conidia in spherical tufts on enlarged ærial hyphæ. The swollen end of an ærial hypha is densely set with cylindrical cells, from which the conidia are abstricted one after another. *Penicillium crustaceum* (figs. 193⁸ and 193⁹) is very similar, but here the conidia are borne on a hypha which branches near its extremity like a compound umbel. Another form, *Eurotium*, is shown in fig. 385⁷, p. 679. The ascus-fruits of these Moulds are not very conspicuous, nor are they always very plentifully developed. They arise on the mycelium after the conidial stage is over, and when ripe are about the size of small shot. They commence by the entwining of certain hyphal branches (*Penicillium*, fig. 193⁶, p. 18; *Eurotium*, fig. 385⁹, p. 679) which have been regarded as representing male and female organs (cf. p. 60). That fertilization takes place is strenuously denied by many modern mycologists, and the sexual nature of the entwining hyphæ is not universally recognized. Be this as it may, the result of the process in question (which also takes place in the Mildews) is the formation of a sinuous hypha, which becomes embedded in a dense cortical sheath which grows up from the mycelium close by the place of origin of the entwined hyphæ. This is the young fruit-body; that of *Eurotium* is shown in section in fig. 385¹⁰. From the central hypha numerous asci, each containing 8 spores, are ultimately developed (figs. 193⁷ and 385¹¹). The ripe ascus-fruit, which frequently takes several months to mature, consists of a hard outer shell containing numerous asci (one of these fruits is shown in fig. 385⁷, in the right-hand bottom corner); it is

able to remain dormant over long periods. *Aspergillus* is sometimes parasitic, and is stated to promote a diseased condition of animal tissues known as *mycosis*. *A. fumigatus* is found growing spontaneously in the air-passages of birds and in the human lungs.

Tuberaceæ.—These are subterranean saprophytes whose mycelia grow in humus. Their fructifications are solid, tuber-like bodies of various sizes. The Truffles (*Tuber rufum*, *T. melanosporum*, *T. æstivum*, &c.) are well-known, and several of the species are esteemed as delicacies. In section the Truffle-fruit shows a curious mottled appearance due to its irregular chambered character. The chambers are filled with hyphæ which produce numerous oval asci, each containing 4 spores (cf. fig. 387¹, which represents an enlarged chamber); the spores are covered with delicate spines. The wall of the fructification consists of a hard parenchyma-like layer, and possesses a rough and warted exterior. As the fructification ripens the mycelium disappears, the Truffles being found detached in the soil. The spores are ultimately liberated by the decay of the fruit. *Elaphomyces* produces fruits about the size of a nut. The mycelium of species of this genus is concerned in the formation of the fungal investment or mantle of the roots of Pine-trees known as mycorrhiza (cf. vol. i. pp. 249, 250); in the Amentaceæ, &c., neither the species nor group to which the Fungi forming this mantle belong has been ascertained.

Pyrenomycetes.—An extremely large and varied group, including both parasitic and saprophytic forms. The essential character of the family is the presence of flask-shaped chambers with a pore at the apex in which the asci are produced. The chambers, the *perithecia*, may be either solitary upon the mycelium in the simpler forms or embedded in receptacles of most varied form (the stromata) in the more complex. Sections of perithecia are shown in figs. 385⁵ and 386⁵. A great many *Pyrenomycetes* possess conidial as well as ascus-fructifications. The conidia may arise in tufts from the surface of the mycelium or in urn-shaped cavities—not unlike perithecia—which have been termed *pycnidia*. As a rule, the conidial precedes the ascal stage. This variety in fruiting has led to the recognition of several forms, which are only stages in the life-history of one Fungus. Consequently, as knowledge extends, many of these supposed species have to be suppressed.

Among the simpler forms may be mentioned *Podospora*, which produces solitary sessile perithecia upon its mycelium. *Polystigma rubrum*, which occurs on the leaves of species of Cherry and Plum, produces a brilliant red spotting on the leaves. The mycelium permeates the internal tissues, and during the summer the conidial receptacles or pycnidia are formed. Later, usually in the following spring, in the fallen leaves, the perithecia arise, and the ascospores now liberated infect the young foliage in the vicinity. *Nectria cinnabarina*, another fairly simple form, occurs as little red cushions on the branches of Horse-Chestnut, Elm, Sycamore, &c.; these cushions burst through the bark budding off conidia (this is the bright red stage), whilst later, as tiny lobes, the perithecia arise upon them, each lobe containing a single perithecium (this is the dull crimson stage). The number of simple parasitic *Pyrenomycetes* is almost endless.

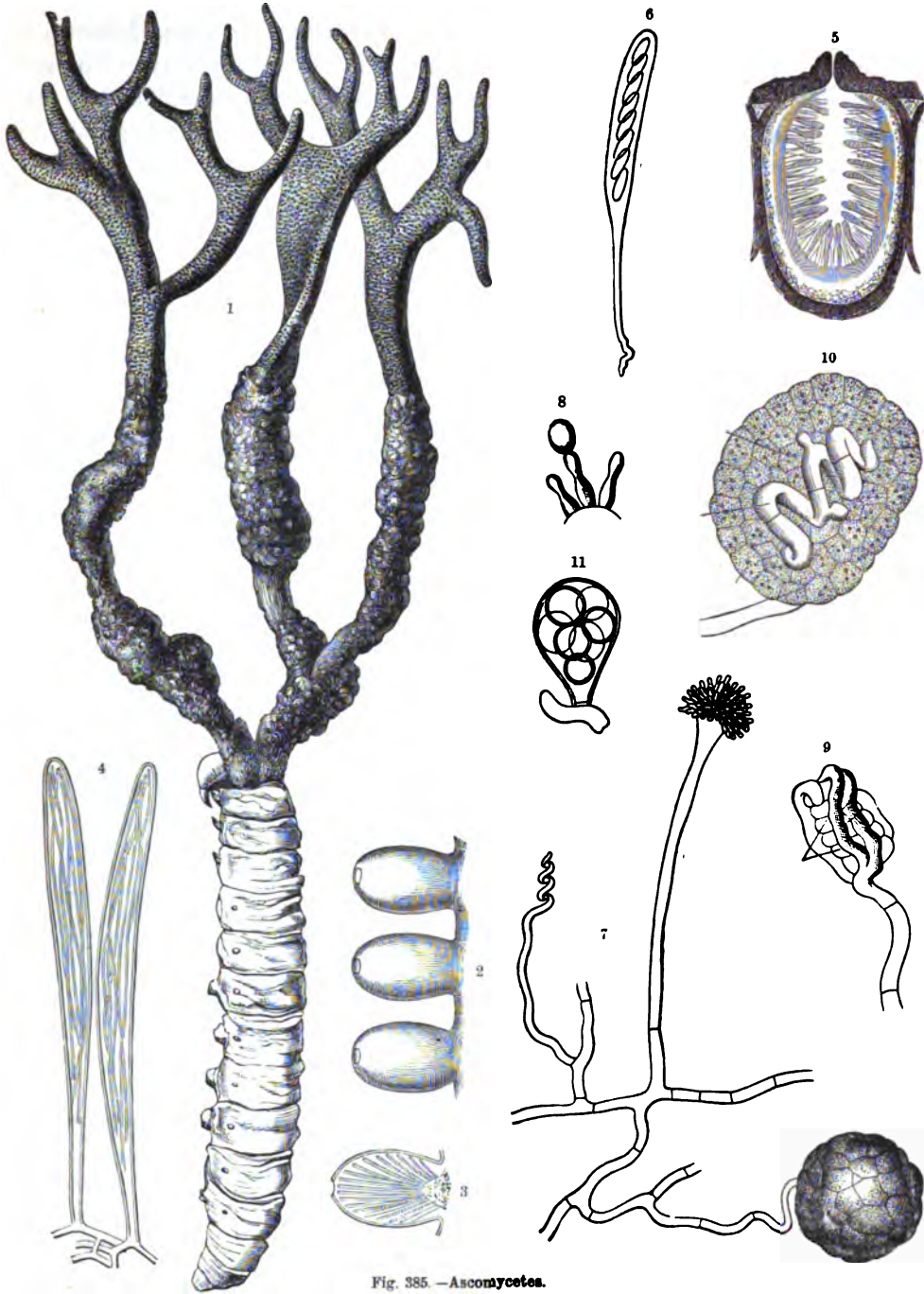


Fig. 385. — Ascomycetes.

1 *Cordyceps Taylori*, a pyrenomycetous Fungus which attacks caterpillars; the branched antler-like stroma has developed from the sclerotium, and its lower warted portion bears the perithecia. 2 Three perithecia; enlarged. 3 A perithecium in section. 4 Two asci containing filamentous spores. 5 Vertical section of a perithecium of *Xylaria Hypoxylon*. 6 Ascus of same. 7 Mycelium of *Eurotium* bearing a conidial hypha (to right, above), a commencing fruit (to left), and a ripe ascus-fruit (to right, below). 8 A conidium of the same being abstricted. 9 Entangled hyphae from which a fruit arises; the spiral central hypha has been interpreted as a female organ, the tubes growing up the side as male. 10 A young fruit of the same in section; the asci arise later from the large coiled central hypha. 11 A single ascus of *Eurotium*. 1 nat. size; 2, 3, 5-90. 4, 6-500; 7-190; 8-11-250.

Of complex forms with stromata we may mention *Cordyceps*, *Xylaria*, and *Claviceps*. *Cordyceps militaris* and other species attack caterpillars. The germ-tube having once effected an entrance into the body of the caterpillar and established itself in the superficial layers begins to sprout vigorously, these sprouts being carried in the blood to all parts of the body. The sprouts now grow into hyphæ, and gradually the whole caterpillar is replaced by a dense fungal tissue which

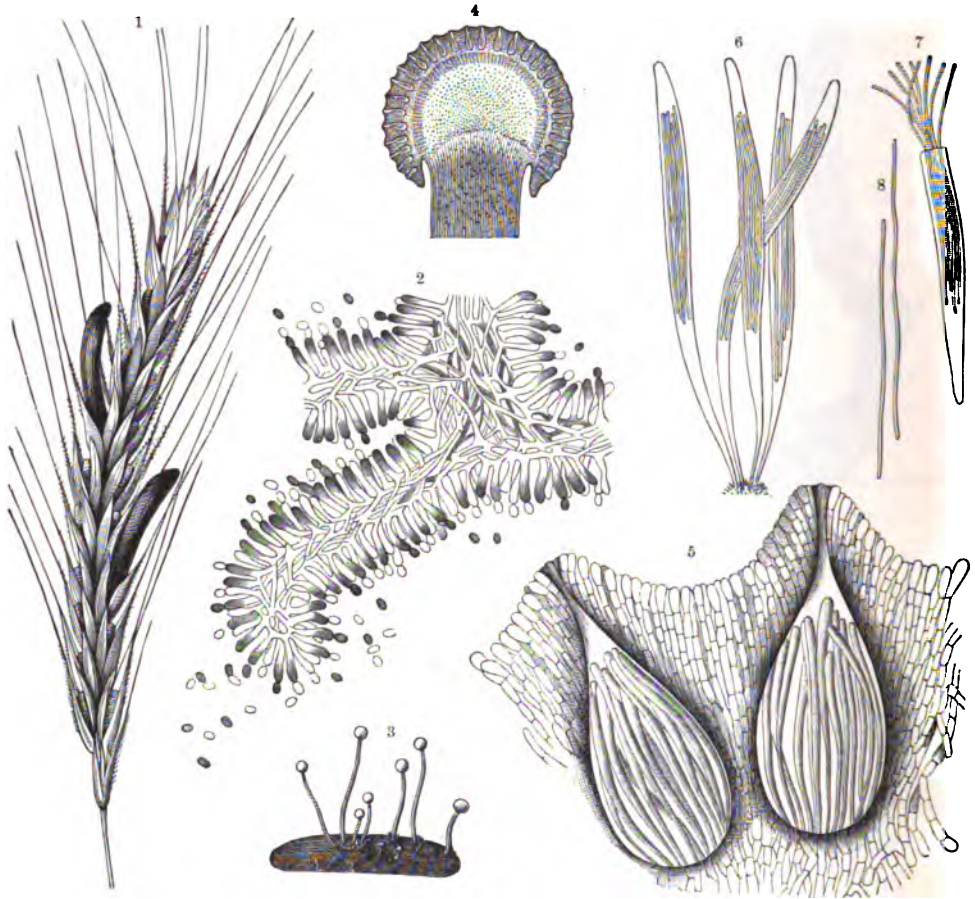


Fig. 386.—The Ergot of Rye, *Claviceps purpurea*.

¹ Ear of Rye showing two sclerotia of the Fungus. ² Conidia arising from the mycelium which develops around the ovary. ³ Stalked stromata arising from the sclerotium. ⁴ Longitudinal section through the head of a stroma showing the perithecia at the edge. ⁵ Vertical section through two perithecia showing the asci. ⁶ Asci. ⁷ Ascus liberating its filamentous spores. ⁸ Filamentous spores. ^{1, 2} nat. size; ³ $\times 200$; ⁴ $\times 40$; ⁵ $\times 50$; ⁶ and ⁷ $\times 700$; ⁸ $\times 750$. (Partly after Tulasne.)

maintains outwardly the form and appearance of the caterpillar, although of animal substance but little traces are left. This fungal mass is known as a *sclerotium*, and it can remain dormant for some time. Ultimately a branching stroma arises from the sclerotium (*Cordyceps Taylora*, fig. 385¹, p. 679), or, in *C. militaris*, several club-shaped stromata. These remarkable stromata are covered with little papillæ on their lower portion, and each of these papillæ corresponds to a perithecium (figs. 385² and 385³). The spores in the asci are long and slender (cf. fig. 385⁴). A

Pyrenomycete which produces an antler-like stroma resembling that of *Cordyceps Taylora*, and which is exceedingly common on old tree stumps, is *Xylaria Hypoxylon*. Indeed, the stroma represented in fig. 385¹ would almost do for that of this *Xylaria*. It is purplish in colour below where the perithecia are borne; at the tips it passes over into a glaucous grey colour, this bloom being due to the conidia, which are abstricted in this region. Another curious fingered species, *X. polymorpha*, is also met with in similar situations. *Claviceps purpurea*, the Ergot

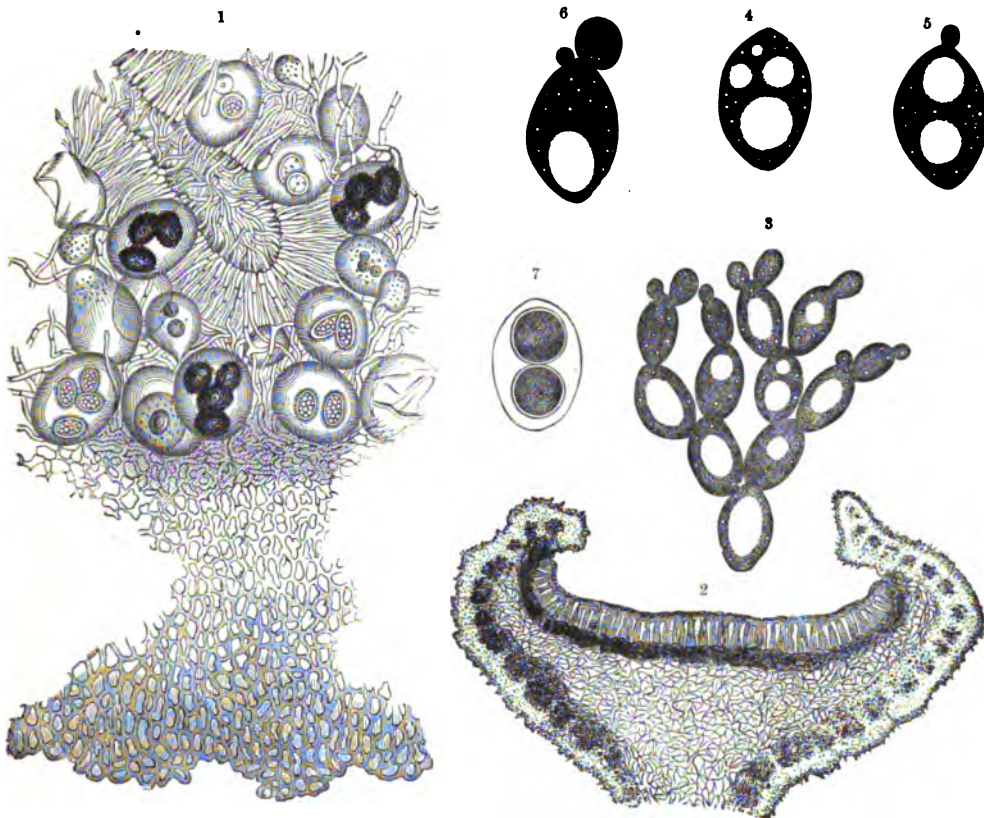


Fig. 387.—Various Ascomycetes.

1 Section through part of a Truffle (*Tuber melanosporum*) showing a portion of the cortex (below) and a chamber containing oval asci, each of which contains 4 spores. 2 Vertical section of the apothecium of a discomycetous Lichen, *Phycia siliaria* (after Sachs). 3 The Yeast-plant, *Saccharomyces cerevisiae*. 4, 5, 6 Single Yeast-cells showing development of a sprout. 7 A cell containing two spores. 1×200; 2×60; 3×600; 4-7×1000. (Partly after Rees.)

of Rye and other grasses, is a very interesting form. The spores attack the ovaries of Grasses and invest them with a mycelium from which conidia are abstricted in large numbers (fig. 386²). These can at once infect new plants. Gradually the whole ovary is replaced by a mass of fungal substance, the sclerotium. In the autumn at the time of harvest the ears of Rye may be seen with these dark sclerotia projecting from them (fig. 386¹). Care has to be exercised that they do not get mixed up with the grain, as the Ergot contains an alkaloid and other poisonous substances, and if intermingled with food causes a disease which has received the name of ergotism. The sclerotia remain dormant through the winter,

but in the spring give rise to their stromata, which consist of a number of orange-coloured spherical bodies borne on purple stalks. A germinated sclerotium is shown in fig. 386³. The head bears the perithecia at its periphery (figs. 386⁴ and 386⁵), and in these are contained the asci with their filamentous spores (figs. 386⁶, 7, 8).

In addition to the forms enumerated above, a large number of pyrenomycetous Fungi are found always associated with Algæ into symbiotic communities known as *Lichens* (cf. vol. i. p. 244). Though in a strict systematic review these forms should be noted here, still, as Fungi from at least two other groups occur in similar relations to Algæ, it will be convenient to treat them all under one heading, rather than scattered over the alliances with which they have a natural affinity (see *Lichenes*, p. 691).

Discomycetes.—These, like the Pyrenomycetes, constitute a very extensive family. They are characterized by the fact that when mature the structure bearing the asci expands into a disc or cup, so that the ascal surface is exposed; or this surface is spread over the outside of a fleshy receptacle.

As a good example of a Discomycete, the large genus *Peziza* may be cited. They are met with chiefly on decaying vegetable matter, and in the various species the disc or cup—the fertile receptacle—is sessile on the mycelium. *Peziza vesiculosa* (cf. fig. 388⁵) is one of the commonest British species, occurring in humus, rotting leaves, &c. Its cups (the apothecia) attain a diameter of 2–3 inches, are buff in colour, fleshy, and very fragile. The inside of the receptacle is everywhere lined with the layer of asci, with sterile hairs, the paraphyses, between (it is similar to fig. 388³). Another common species is *P. scutellata*; it forms little flat red discs about the size of sixpenny-pieces upon rotting wood, and the margin is set with hairs. Several of the *Pezizas* are stalked (cf. figs. 388³ and 388⁴). *P. æruginosa* is an interesting form; it also is stalked, and grows especially upon dead branches of Oak. It permeates the wood with its mycelium, and this appears to excrete a green pigment which stains the wood in its vicinity. The stalked apothecium is also green in colour. This green-rotting wood is exceedingly common and is used in the manufacture of "Tunbridge ware"; the actual Fungus, however, is by no means so obvious, and from the majority of green-rotted branches not only has the apothecium disappeared, but the mycelium also. Resembling a *Peziza*, but very gelatinous, is *Bulgaria inquinans*, common on decaying trunks of trees. *Peziza Willkommii*, causing the Larch-canker, has been already referred to (cf. p. 522). Nearly related to the *Pezizas*, and causing parasitic diseases of plants, is *Sclerotinia*. It possesses a well-marked sclerotium, from which stalked *Peziza*-like apothecia are produced. A species not uncommon in this country is *Sclerotinia tuberosa*. It attacks the underground parts of Wood Anemones and forms its sclerotia in the tubers of this plant. In the spring, instead of Anemone-flowers coming up, the sclerotium gives rise to a number of long-stalked apothecia which appear just above the surface of the ground.

Other more complex Discomycetes are the *Helvellas* and *Morels*, forms purely saprophytic. *Helvella* produces a stalked receptacle, curiously folded (see figs. 388⁶

and 388⁷) and plaited; the whole of the exposed surface of this receptacle is covered with asci. The Morel (*Morchella esculenta*, fig. 388¹) possesses a thick stalk bearing a large fleshy receptacle marked out in pitted areas. Nearly allied is the genus *Geoglossum*, possessing club-shaped receptacles, black in colour, and covered with asci. *G. difforme*, 2–4 inches high, is often met with among grass in the autumn.

The *Lichenes* belonging to this family are treated with the other Lichens at p. 691.

Reference to a small group of forms, the *Saccharomycetes* or Yeasts, may be

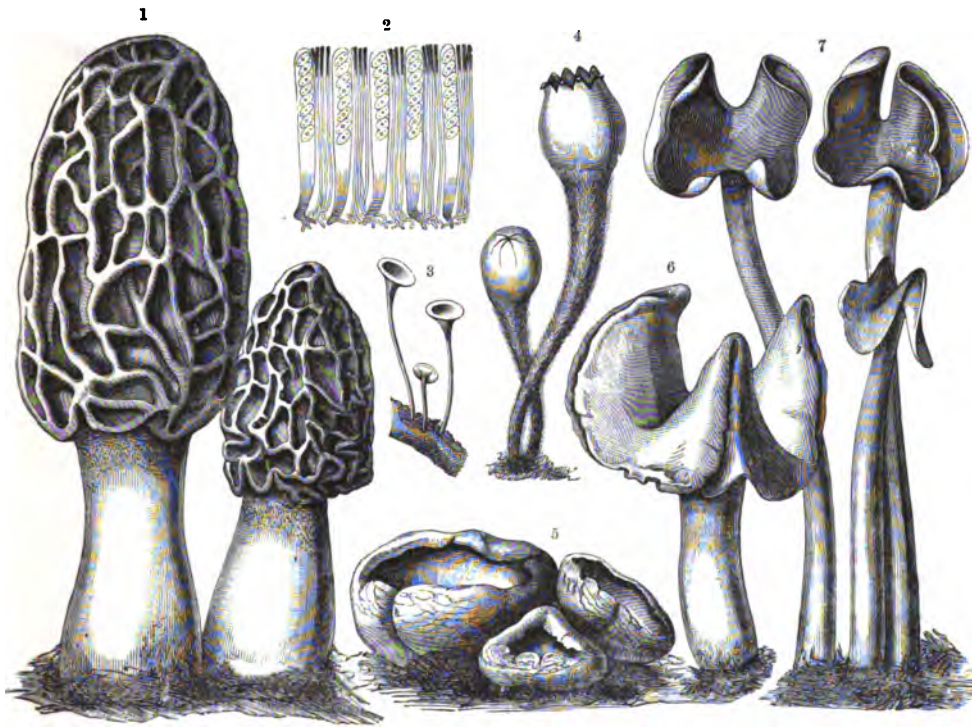


Fig. 388.—Discomycetes.

¹ The Morel (*Morchella esculenta*). ² Vertical section of the fertile surface of the Morel showing five asci with their spores and filamentous paraphyses between the asci. ³ *Peziza* (*Helotium*) *Tuba*. ⁴ *Anthopeziza* *Winterei*. ⁵ *Peziza* *vesiculosa*. ⁶ *Helvella* *infula*. ⁷ *Helvella* *fistulosa*. ¹, ⁴, ⁶, ⁷ nat. size; ² $\times 4$; ³ $\times 120$.

introduced here. They constitute a detached family with ascomycetous affinities, and characterized by their very peculiar mode of life. For the most part they do not form mycelia, but increase by budding and by the formation of spores. *Saccharomyces cerevisiae* is the well-known Brewer's Yeast. The cells are oval and colourless, and provided with one or more conspicuous vacuoles; the cell-nucleus is not readily demonstrable, though there is little doubt of its existence. Growth here is by budding, little processes being pushed out at the periphery at one or more spots and gradually enlarging (figs. 387^{4,5,6}); ultimately they are cut off from the parent-cell by the completion of the membrane across the point of union. In this

way groups of cells may hang together in chains (fig. 387³) for a short time, but they disarticulate sooner or later. As the substratum becomes exhausted the cells exhibit a tendency to form spores in their interior (2-8), the cell being as it were transformed into an ascus (fig. 387⁷). The special physiological activity associated with this and several other species is alcoholic fermentation (*cf.* vol. i. p. 506), *i.e.* the splitting up of sugar into alcohol and carbonic acid. *S. cerevisæ* is used in brewing, *S. ellipsoideus* causes the fermentation in the juice of the Grape.

S. mycoderma forms a scum on wine and beer, and is of interest in that it produces mycelial tubes.

In all there are some 40 species of *Saccharomyces*.

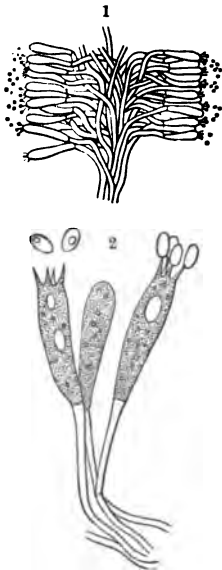


Fig. 389.

¹ Portion of a lamella of an *Agaricus* with a basidial layer (from which conidia are being budded off) on either side. ² Shows three basidia, more highly magnified, from the basidial layer of the same fungus; conidia are being abstricted from the four processes (sterigmata). ¹ $\times 200$; ² $\times 500$.

Alliance XIX.—Basidiomycetes.

Parasites and saprophytes, reproducing by means of conidia which arise on basidia in definite number. Besides these characteristic conidia there are subordinate fructifications.

Families: *Uredineæ*, *Auriculariaceæ*, *Tremellaceæ*, *Pilacraceæ*, *Dacromycetes*, *Hymenomycetes*, *Gasteromycetes*.

The Basidiomycetes are an exceedingly large alliance, and include forms from the simplest to the most complex. They all agree, however, in the production of conidia from a definite *basidium*, a character which gives its name to the group. As has been already pointed out (p. 674) there are two families in the Hemibasidii, *i.e.* the *Ustilaginaceæ* and the *Tilletiaceæ*. In both families a promycelium or basidium arises from the chlamydospore; in the former it is septate and conidia are cut off laterally, in the latter it is non-septate and the conidia are produced in a tuft at the extremity. In the *Uredineæ* a basidium arises from each cell of the teleutospore (the probable equivalent of a chlamydospore), and this basidium is transversely septate, four cells being cut off at the end of the tube away from the spore. Each of these cells produces a little process, and from each process a conidium is abstricted. In all the other families of Basidiomycetes the teleutospore (or chlamydospore) is suppressed, and the basidia are directly continuous with the hyphæ of the Fungus. Otherwise, the basidia of *Auriculariaceæ*, *Tremellaceæ*, and *Pilacraceæ*, all belong to the type of the *Uredineæ*, and are derivable from the *Ustilago*-form. On the other hand, the basidia of *Hymenomycetes* and *Gasteromycetes*, and probably also of *Dacromycetes*, belong to the *Tilletia* type (*cf.* p. 675). The conidia do not arise laterally, but from four processes at the tip of an unsegmented basidium (see figs. 389² and 390⁷). The very general restriction of the number of processes arising on the basidium to four is without doubt a feature of some importance, and

is a further justification for the inclusion of all these families—at first sight so different—in a single alliance.

Uredineæ.—These are the Rust-fungi, parasites for the most part on the foliage of higher plants. They are outwardly manifest in the form of yellow or brown



Fig. 390.—Basidiomycetes.

1 *Clavaria aurea*. 2 *Daldia quercina*. 3 *Marasmius tenerrimus*. 4 *Marasmius perforans*. 5 *Craterellus clavatus*. 6 *Amanita phalloides*. 7 A portion of the basidial layer of the last-named Fungus showing the sterigmata and conidia. 8 *Hydnum imbricatum*. 9 *Polyporus perennis*. 7 $\times 250$; the rest nat. size.

spots and streaks, due to the spores, which are formed in masses on the surface. The mycelium inhabits the intercellular system of the host-plant, and draws its nourishment from the living cells. The spores are regarded as chlamydospores, that is to say, localized, thick-walled segments of the hyphæ having the properties of reproductive cells. These spores are met with in three forms in the *Uredineæ*. The

Teleutospores (from *τελευτή*, an end), which are the type most universally present, arise towards the end of the vegetative period. In the majority of cases they remain dormant during the winter. On germinating they form a 4-celled basidium, from each cell of which a conidium is abstricted. Commonly the teleutospores are in rows of two, *i.e.* constitute spindle-shaped, 2-celled bodies, each cell (spore) of which can produce a basidium. Sometimes the teleutospores are in many-celled rows, occasionally solitary. The *Uredospores* (from *uro*, to burn) as a rule precede the teleutospores and germinate at once. They are oval and unicellular. The *Æcidiospores* arise in chains in special receptacles (the æcidium-fruits) which are at first closed. Both uredospores and æcidiospores differ from teleutospores in that they produce a mycelium at once on germination. They never form basidia and conidia. A fourth sort of reproductive organ, a secondary conidial stage, is often found associated with the æcidium stage; this is the pycnidium (*cf.* p. 678), a hollow receptacle whose lining cells abstract tiny conidia. The fate of these pycno-conidia and the part they play in the life-history of the Fungus is unknown.

There is thus in the Uredinæ great variety in the kinds of reproductive cells. Some species possess all of them and produce them one after another upon the same host-plant (e.g. *Puccinia galii* and *P. primulæ*); others possess teleutospores only or teleutospores and one of the other types, whilst in others again all the forms are present, but they are not developed upon the same host-plant. This latter property of developing the different stages on two host-plants (known as *heterœcism*) is by no means uncommon amongst the Uredinæ. It is remarkable enough to merit a short description here, though, of course, any exhaustive account of the family as a whole is impossible. The following are well-known cases of heterœcism. *Coleosporium senecionis*, which produces its uredospores and teleutospores on the Groundsel (*Senecio vulgaris*), its æcidiospores on *Pinus sylvestris* (the latter stage formerly known as *Peridermium pini*); *Puccinia graminis*, which produces its uredospores and teleutospores on Wheat and other grasses, its æcidiospores on the Barberry (this stage formerly known as *Æcidium berberidis*); *Gymnosporangium juniperinum*, which produces its teleutospores on the Juniper, its æcidiospores on the Mountain Ash (*Pyrus aucuparia*). These three may serve as types of a very large number of similar forms. *Puccinia graminis*, the Rust of Wheat, is the most famous of all. The æcidium-stage (accompanied by pycnidia) arises in spring on the foliage of the Barberry and the æcidiospores here produced cannot germinate on the same host, but only on Wheat, Oats, Rye, or some other Grass. Here a new mycelium is established bearing first uredospores and later on teleutospores. The uredospores can germinate at once on other grasses, but the teleutospores remain dormant through the winter, and in spring give rise to basidia from which conidia are abstricted; these conidia can germinate only on the Barberry—not on grasses—and from the mycelium which arises from them fresh æcidium-fruits are developed. In the absence of either host-plant (*i.e.* of the Barberry or of suitable Grasses) the life cycle of the *Puccinia* is of course interrupted. For the extermination of the Rust disease of cereals the removal of Barberry bushes is an obvious measure. In

parts of Europe, however (e.g. many upland valleys in Switzerland) this precaution is not taken and the *Æcidium*-covered Barberries and rusted crops may be seen standing side by side. It is true the rust does not destroy the wheat crop entirely but it seriously diminishes the yield of grain. Long before the life-history of the Rust-fungus had been scientifically traced the Barberry was known to have an evil influence upon cereals. So long ago as 1760 the state legislature of Massachusetts passed an Act¹ compelling the inhabitants to extirpate all Barberry bushes. The main facts connected with the life-history of *Gymnosporangium* have already been mentioned (cf. p. 522), and the two stages are represented on p. 521. The projecting lobes on the Juniper (fig. 357¹, page 521) consist of masses of teleutospores embedded in mucilage. When wetted they swell up, the basidia are produced and the conidia abstricted; the latter are then blown away and, should they alight upon the young foliage of a suitable member of the Pomaceæ, penetrate the tissues and produce the *Æcidium* stage. The effects of various other members of this group are referred to on pp. 524, 525. Between four and five hundred parasitic Uredineæ have been distinguished.

Auriculariaceæ.—Include the well-known Jew's-ear Fungus (*Auricularia sambucina*) not infrequent on dead branches of the Elder. From its fertile surface basidia with conidia resembling those of the last family are produced, but the basidia are continuous with the hyphæ of the Fungus, no chlamydospores being produced.

Tremellaceæ.—Gelatinous forms found on rotting tree-trunks. Their substance is curiously lobed and plaited; *Tremella Mesenterica*, which forms large gelatinous orange masses on dead branches, is the commonest of them.

Pilacreæ.—Include a single genus only, *Pilacre*; it grows on Beech-bark, and consists of a spherical head mounted on a stalk. It is of interest because its basidia (from which the conidia are abstricted) are inclosed in a loose layer of hyphæ—the outward continuations of the hyphæ upon which the basidia are borne—and it is thought to lead on the family of the Gasteromycetes, in which the basidia are entirely covered in.

Dacromycetes.—Gelatinous forms resembling the Tremellaceæ. They approach the Hymenomycetes in that their basidia are destitute of septa. The processes from which the conidia are abstricted are very long. *Dacromyces deliquescens* is common as a red-coloured tough gelatinous mass on wooden palings.

Hymenomycetes.—An extensive family characterized by the production of a

¹ THE BARBERRY LAW OF MASSACHUSETTS.—Anno Regni Regis Georgii II. Vicesimo Octavo, Chap. X. (published January 18, 1755).

An Act to prevent Damage to English Grain arising from Barberry Bushes.

Whereas it has been found by experience, that the Blasting of Wheat and other English grain is often occasioned by Barberry Bushes, to the great loss and damage of the inhabitants of the Province:—

Be it therefore enacted by the Governour, Council, and House of Representatives, that whoever, whether community or private person, hath any Barberry Bushes standing or growing in his or their Land, within any of the Towns in this Province, he or they shall cause the same to be extirpated or destroyed on or before the thirteenth Day of June, Anno Domini One Thousand Seven Hundred and Sixty. And so forth. (From Plow-right's *British Uredineæ*.)

fertile surface (the *hymenium*) consisting of basidia with 4 processes (or *sterigmata*) from each of which a conidium (or *basidiospore*) is abstricted. Typical basidia are represented in fig. 389², p. 684, and fig. 390⁵. The hymenium in this group is exposed at the time when the basidiospores are produced.

As in the Ascomycetes, so here, there is an extensive range of forms from simple to complex. Simplest of all are the *Exobasidæ*, mostly parasites on Ericaceæ. *Exobasidium Rhododendri*, which causes the Alpine Rose apples, has already been mentioned (p. 520), as also *E. Vaccinii* and *E. Lauri* (p. 526). The hymenium in these simple forms is produced over the whole surface of the hypertrophy or blister caused by the Fungus. In the *Telephoreæ* a definite tissue bearing the hymenium is developed; this is termed the hymenophore or fructification. In the simple *Corticium* this forms smooth sheets of waxy nature everywhere encrusting the substratum. The basidia occur over the free surface. *Stereum*, also very common on old trunks, forms leathery plates usually attached laterally or stalked. The hymenium is on the smooth under surface, whilst the upper surface of the fructification is more or less velvety. *Craterellus* (fig. 390⁷), laterally attached, is hollowed out above; the under surface is the fertile one. In the *Clavariæ* the fructification is club-shaped and fleshy, and covered externally by the hymenium—as in the sulphur-yellow *Clavaria inæqualis* very common on grass lawns and pastures—or it is branched and coral-like as in *Clavaria aurea* (fig. 390¹). In the *Hydneæ* there is a well-marked distinction into a stalk and cap (known as the *pileus*); the hymenium is on the under surface, and is in the form of a number of crowded spines or teeth (e.g. *Hydnum imbricatum*, fig. 390⁸). The *Polyporeæ* form a large and important group, characterized by the fact that the hymenium has the form of a number of pits, tubes, or meshes, usually on the under surface of the fructification. The simplest of these is the Dry-rot Fungus, *Merulius lacrymans*. The mycelium of this Fungus penetrates the substance of ill-preserved woodwork in houses, disintegrating it and reducing it to a brittle consistency. At places it produces fructifications, flat irregular bodies whose under surface, the hymenium, consists of a honeycombing of shallow depressions. The property which these fructifications possess of excreting drops of water has given to this Fungus the name *lacrymans*. In *Polyporus* the hymenium has the form of numerous fine tubes lined with basidia. The fructification may be either bracket-like, as in *Polyporus fomentarius* (growing on the Beech-trunk to the right hand of Plate XIV.), or it may have the cap-like form of a mushroom mounted on a central stalk, e.g. *P. perennis* (fig. 390⁹) and the allied *Boletus edulis* (Pl. XIV. left-hand bottom corner). To these Polyporuses belong some of the most destructive diseases of timber, their myceliums penetrating the wood everywhere, softening and disintegrating it (e.g. *Polyporus igniarius*, *P. fomentarius*, *P. sulphureus*, and *P. annosus*—otherwise known as *Trametes radiciperda*). The last-named *P. annosus* causes a well-known disease of coniferous timber, the wood coming out in white spots before it is finally disintegrated. It is of interest because the fructifications are produced on the roots of the trees attacked. Allied to *Polyporus*

is *Dædalia* (fig. 390^a) a bracket-like form in which the hymenium takes the form of irregular branching slits on the under surface. The *Agaricineæ*, which include the very numerous mushroom and toadstool Fungi, are for the most part umbrella-like in form, having a central stalk and expanded circular receptacle (the pileus). The under surface of the pileus is occupied by lamellæ or gills which radiate from the insertion of the stalk to the margin of the pileus (cf. figs. 390^{a, b, c}). The basidia forming the hymenium are set upon the sides of these gills. Fig. 389¹ shows an enlarged section through a part of a gill. In the more complex forms certain structures are present inclosing the young fructification, but they are ruptured as the pileus expands, and in adult fructifications the gills are freely exposed. Their remains may often be seen on the mature Fungus, as in *Amanita* (fig. 390^c). Just below the pileus there is a membranous ring (the *annulus*); at an earlier period it was attached to the margin of the pileus covering in the hymenium, and forming what is termed the *velum partiale*. In the same Fungus may be noted the remains of another sheath, the *velum universale*, which enwrapped the entire fructification. This is shown in fig. 390^c as a ruptured sheath (the *volva*) at the base of the stalk, whilst portions of the covering which invested the pileus (and was continuous with the ruptured sheath alluded to) are to be seen as white felty patches on the scarlet pileus of *Amanita muscarius* (cf. Plate XIV.). The forms and varieties of the *Agaricineæ* are far too numerous even for mention. Many of them are edible, notably the Mushroom, *Agaricus campestris*, and the yellow-coloured *Cantharellus cibarius* (allied to the *Agaricineæ*, Plate XIV. on the left). Others again are poisonous, as, for instance, the scarlet *Amanita muscarius* (Plate XIV.), which receives the name *muscarius* from the fact that decoctions of this Fungus were formerly used for killing flies. Certain forms (*Russula* and *Lactarius*) contain a latex of a white or yellow colour. A number are characterized by producing sclerotium-like bodies (cf. p. 681). As a rule in the *Agarics* the fructifications arise directly from the mycelium, but in *Coprinus stercorearius*, *Lentinus*, &c., tuber-like masses of fungal substance are formed, and it is from these that the fructifications arise. These sclerotia, often attaining large dimensions, have been found by travellers in various parts of the world, and the fructification which arises from them is not in all cases known. Several of them, formerly name *Pachyma*, &c., are now known as belonging to the genus *Lentinus*. Very curious are the string-like sclerotia of *Agaricus melleus* which, from their root-like nature, were formerly termed "Rhizomorphs". They are found especially in Conifers, growing between the wood and bark, and having a ribbon-like form; from them cylindrical branches may arise which penetrate the soil and attack the root of some other tree. Ultimately the mushroom-like fructifications arise from these rhizomorphs.

A few lichens derived from the Hymenomycetes are treated at p. 695.

Gasteromycetes.—These are characterized by the fact that the basidia arise in closed chambers, which collectively constitute the *gleba*, and that this is covered by a continuous cortex or *peridium*. They include the Puff-balls, Earth-stars, Stink-

horns, &c. They are all of them more or less subterranean saprophytes, appearing above the surface to discharge their spores. The arrangements for the accomplishment of this purpose are very varied. The Puff-balls include the genera *Lycoperdon*, *Bovista*, *Scleroderma*, &c. When young a large portion of the interior has a chambered structure (the gleba), and in these chambers the spores are budded off. At maturity the fructification appears above the surface of the ground, and the whole of the substance of the walls of the chambers breaks down, except for certain branching threads (the *capillitium*, see fig. 391³), which persists along with the

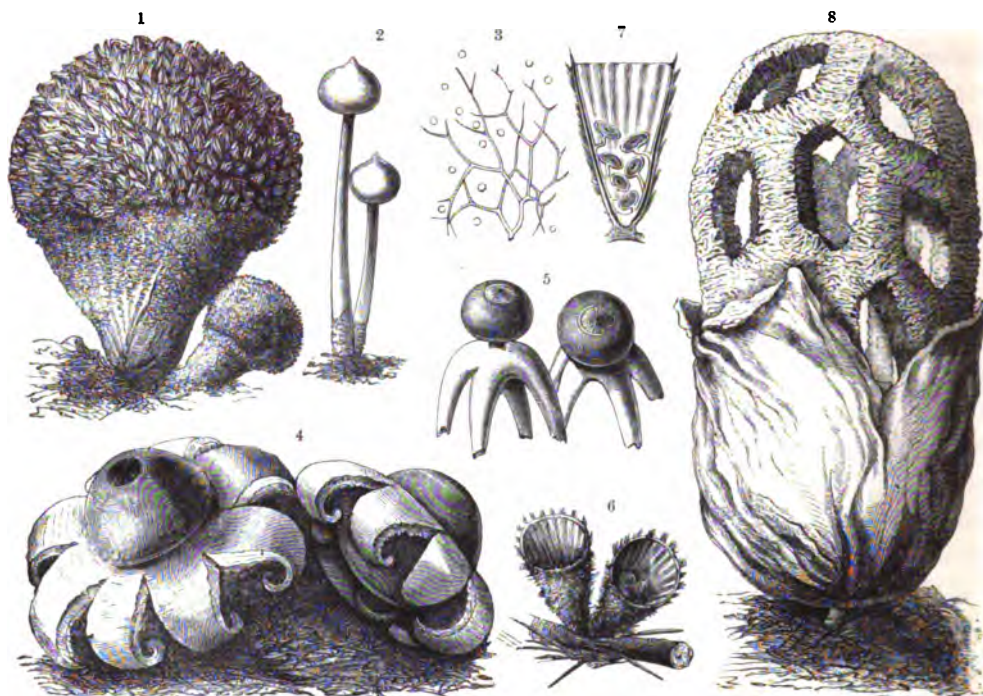


Fig. 391.—Gasteromycetes.

¹ *Lycoperdon constellatum*. ² *Tulostoma mammosum*. ³ Capillitium and spores of *Tulostoma*. ⁴ *Geaster multifidus*. ⁵ *Geaster fornicatus*. ⁶ *Cyathus striatus*. ⁷ Longitudinal section of same. ⁸ *Clathrus cancellatus*. ⁸ $\times 80$; ⁷ slightly enlarged; the rest nat. size.

minute spores (*Scleroderma* has no capillitium). The latter escape by the peridium becoming perforated. *Lycoperdon* (see fig. 391¹) differs from *Bovista* in having a sterile basal portion, which is sometimes considerably elongated. In *Tulostoma* (fig. 391²) the outer layer of the peridium bursts and the sterile basal portion elongates considerably, hoisting up the gleba inclosed in an inner peridium. The Giant Puff-ball (*Lycoperdon giganteum*) sometimes attains huge dimensions—occasionally a metre in diameter. Allied to the Puff-balls is *Geaster*, the Earth-star (figs. 391⁴ and 391⁵). In this genus the outer peridium splits into segments and folds back, the inner peridium becoming perforated and liberating the spores. Earth-stars are met with now and then, but they are not usually very common. In *Cyathus* (figs. 391⁶ and 391⁷) we have a form resembling a little bird's-nest

containing eggs. Here the chambers, instead of being numerous and deliquescent as in *Lycoperdon*, are few and provided with thick, hard walls; they arise in a matrix which occupies the whole body of the Fungus, and when mature they become isolated by the disappearance of the matrix. Each chamber is attached by a string to the wall of the peridium (*cf.* fig. 391⁷). The opening at the top arises by the coming away of a membrane which previously closes it in. Perhaps the most remarkable group of Gasteromycetes is the *Phalloideæ*, which includes the common Stink-horn Fungus and other forms. Whilst immature they are egg-like, but at ripening the investment bursts and the remarkable gleba is hoisted up. *Clathrus* (shown in fig. 391⁸) has its gleba spread over a hollow spherical lattice-work; the gleba is red in colour and the appearance of the Fungus very striking; it is rare in this country. The Stink-horn, *Phallus impudicus*, is less rare. When the gelatinous investment bursts, a spongy, spindle-shaped stalk expands and raises up the green, cap-like gleba. The *Phalloideæ* depend upon insects for the dispersal of their spores. Flies are attracted by the bright coloration and foul smell of these Fungi, and they lick up the mucilage into which the gleba deliquesces with great avidity. Perhaps the tropical *Dictyophora phalloidea* is the most remarkable of the group. It resembles a *Phallus*, but unfolds around itself a delicate white network which hangs expanded from below the gleba-cap like a crinoline. It is thought that this appendage—like the white corolla of a night-flowering plant—renders the Fungus additionally conspicuous after dark. The *Phalloideæ*, in reference to their marked attraction for insects, are sometimes spoken of as the "Flowering Fungi".

ADDITIONAL GROUP OF FUNGI

LICHENES.

In our review of the various alliances and families of Fungi the fact has been from time to time noted that certain members of various groups live symbiotically with Algæ as Lichens. Though obviously all these Lichen-fungi do not constitute a natural group or alliance, we propose treating them for convenience together. The general characters of Lichens and their mode of life have been already indicated in the chapter commencing at vol. i. p. 243; consequently little but an enumeration of the groups of Lichens and their methods of reproduction is required now. Briefly, a Lichen consists of a Fungus and an Alga upon which the Fungus lives parasitically. But it is something more than a mere parasitic Fungus on a green plant. The mycelium involves the Alga in the most complete manner (*cf.* fig. 392), but it doesn't kill it like an ordinary parasite. It lives upon the organic food which the Alga is able to manufacture in virtue of its chlorophyll, but without obvious injury to the Alga. Indeed, the algal cells often attain to a larger size and greater brilliance of colour than when growing freely. On the other hand, the Alga is nowhere in contact with the substratum (being inclosed in the substance of the Fungus), so that water

and dissolved salts are absorbed and supplied it by the Fungus. It is also protected by the Fungus, and able to exist in places where it could not live alone. Thus, for the Lichen, we speak of *symbiosis*, a living together. 'Tis true the Fungus is the predominant partner in this association, but it is not a parasite in the common acceptation of that term. Further, as predominant partner it is the Fungus which determines the form of growth and takes the initiative, the Alga following after. But even to this rule an exception has been found, and very likely others exist. For where two organisms live together, as in the Lichen, it may well happen that conditions may exist under which the Fungus can only control the Alga with difficulty, and that the Alga, attempting as it were to escape, compels the Lichen-fungus to follow it, not to lead. This indeed seems to be the case in one of the forms of that most remarkable of all Lichens, *Cora pavonia*, to be referred to below.

The conception of the Lichen as a dual organism, compounded of Fungus and Alga, is of relatively modern origin. Its establishment is due to the researches of Schwendener, which date back some thirty years, and to those of Bornet, which shortly followed them. Since those days the continued study of Lichens has tended only to secure for the "Schwendenerian theory" (as it was formerly termed) a more wide and universal recognition. Previous to the Schwendenerian epoch the Alga was regarded as a definite portion of the Lichen-thallus, its cells as arising from the hyphæ of the Fungus; indeed the Algæ were termed "lichen-gonidia". And for many years was the new view opposed by the majority of professed Lichenologists; but into this old controversy we have not space to enter here. It is sufficient to say that the Algæ of Lichens are referable to known genera and species of free-living Algæ, and that they have been determined for a number of cases. The Alga freed from the Lichen-fungus pursues its normal mode of life, and can then be identified; this is not always possible so long as it remains within the Lichen, owing to the change which the Fungus calls forth in it. It is a noteworthy fact that hitherto no Alga has been found so completely adapted to lichenism that it could not attain to its normal development outside the Lichen-thallus. On the other hand, Lichens have been raised from the spores of the Lichen-fungus allowed to germinate on free-growing Algæ. In this way a number of Lichens have been synthesized; and it has been shown that one and the same species of Alga could serve for several Lichens. Finally, the spores of Lichen-fungi have been grown on nutrient solutions, and have attained to advanced stages of development. In nature, however, with one exception (*Cora*, see below), it is not certainly known that any Lichen-fungus can grow independent of its Alga as substratum. We must regard the Lichen-fungi as being members of various Fungus-families which have become so specialized to a peculiar form of nutrition that under ordinary circumstances they do not develop upon anything except their Algæ. The Fungus-forms which occur in Lichens are vastly more numerous than are the Algæ; indeed the latter are drawn from relatively few families—from the Chroococcaceæ and Nostocaceæ of the Blue-green Algæ, and from the Protococcoidææ, Confervoidææ,

and Coleochæteæ of the class Gamophyceæ of Green Algæ. Thus the same Alga serves for many different Lichens.

Classifying Lichens according to the characters of the fungal constituent, we find members of the following families: Discomycetes, Pyrenomycetes, Hymenomycetes, and Gasteromycetes. We may therefore speak of 4 families of Lichens:

Discolichenes, *Pyrenolichenes*, *Hymenolichenes*, and *Gasterolichenes*.

Discolichenes.—All produce asci in apothecia after the manner of Discomycetes (*cf.* p. 682). The apothecia arise in numbers on the surface of the Lichen-thallus (*cf.* figs. 393¹, 394, and 387²), and the spores are formed in the asci in the usual way. In many genera the spores are multicellular. In not a few cases there are arrangements for the simultaneous distribution of the Alga-cells along with the

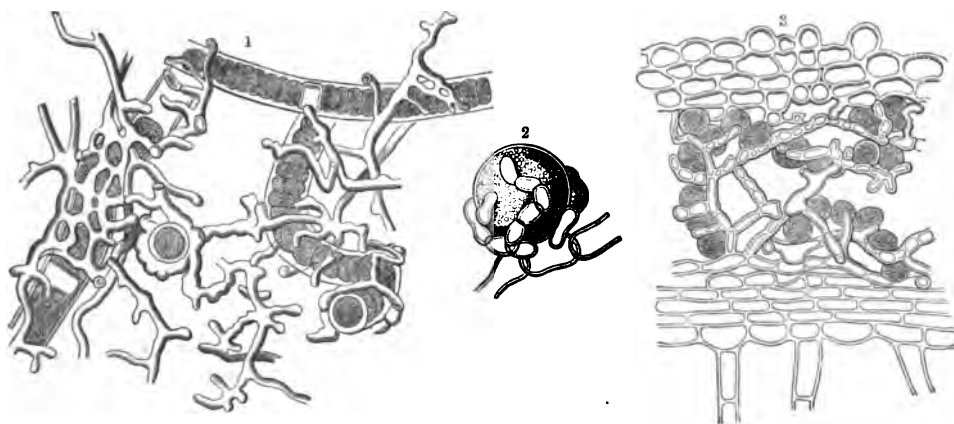


Fig. 392.—Lichens.

¹ Hyphae of *Stereocaulon ramulosum* enveloping filaments of the blue-green Alga *Scytonema*; $\times 650$. ² *Cladonia furcata* with *Protococcus*; $\times 950$. ³ *Cocciocarpia molybdæa*, section of thallus; $\times 650$. (After Bornet.)

ascospores, so that it shall not be left to chance for the spores to alight upon a suitable Alga. In these cases the algal cells bud actively below the layer of asci, and some are pushed up between the asci at the time when the latter reach maturity. Many Lichens possess also conidial fructifications, known as pycnidia (*cf.* p. 678). These are flask-like excavations, into which tiny conidia are budded by the lining cells. These receptacles were formerly termed spermogonia and the conidia spermatia; but the evidence that they have any such function as the terminology suggests is of the most slender description. On the other hand, these conidia have been caused to germinate and produce characteristic Lichen-thalluses in a number of cases. Pycnidia may be easily seen in the Iceland Moss (*Cetraria islandica*); they occur one in each of the tiny teeth on the margins of the ribbon-like thallus. Very common is vegetative propagation by means of brood-bodies known as *soredia*. These arise as little buds below the surface, and consist of an algal cell or two and a weft of fungal hyphae. Being formed in quantities together they burst through to the surface as a dust-like powder and constitute the "soredia-heaps". They are distributed by the wind or washed away by rain. Both constituents of the Lichen

being present, they readily grow into fresh Lichens. In the majority of Lichens the Algæ are arranged in a definite layer or stratum (*cf.* figs. 392² and 387²); rarely are they distributed through the whole thickness of the thallus, as in the Gelatinous Lichens (*Collema*, fig. 393³). Apart from these Gelatinous Lichens, the Discolichenes may be divided, according to their form, into Crustaceous, Foliose, and Fruticose Lichens. Crustaceous Lichens include such as are everywhere attached to their substratum (stones, bark of trees, &c.) and cannot be removed without injury. As examples may be mentioned the *Lecideas*, many of the *Lecanoras*, &c. The Foliose Lichens are not thus firmly attached; the thallus forms a shield- or ribbon-like expansion, readily separable from its substratum, as, for instance, the well-known orange Lichen *Physcia parietina*, the green-hued *Peltigera canina* (Pl. XV.), with

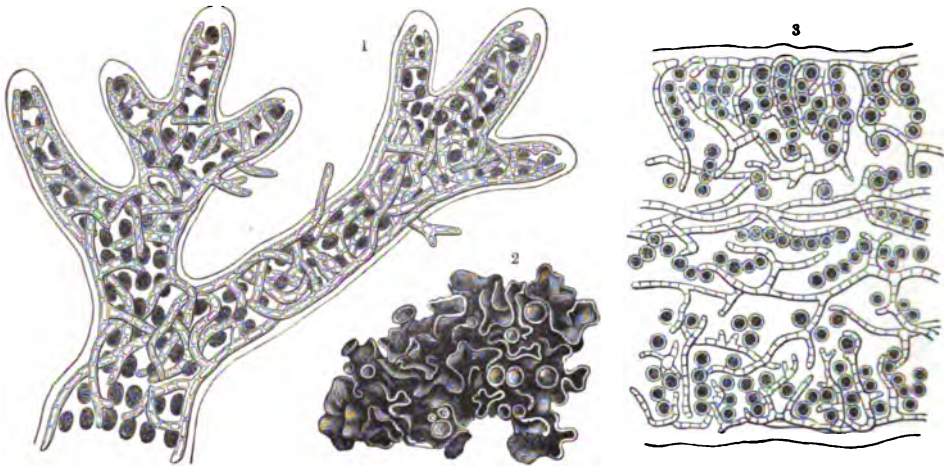


Fig. 393.—Gelatinous Lichens.

¹ *Ephete Kernerii*; $\times 450$. ² *Collema pulposum*; nat. size. ³ Section of thallus of *Collema pulposum*, with *Noctoc* as Alga; $\times 450$.

projecting umber apothecia, common in moist places amongst moss and stones, *Umbilicaria*, and many others. In the Fruticose Lichens the plant is only attached at one place, and has a shrub-like, branched appearance. Here are included many elegant and well-known forms, including *Usnea barbata*, the Old Man's Beard Lichen (Pl. XV.), which hangs in tufts and festoons from the branches of trees, and sometimes produces large disc-like apothecia the size of sixpenny pieces. Another of these epiphytic forms is *Ramalina reticulata*, a Californian form which forms beautiful gray-green, ribbon-like nets. Nor must *Cetraria islandica*, the Iceland Moss (Pl. XV.), and the *Cladonias* be omitted. The last-named are glaucous and generally erect-growing and branched. They include *Cladonia pyxidata*, the familiar Cup-moss (Pl. XV.), *C. rangiferina*, the Reindeer-Moss (Pl. XV.), and *C. coccifera*, growing on heaths with its scarlet, and *C. macilenta* (Pl. XV.), with orange apothecia.

Pyrenolichenes.—In these the asci are contained in perithecia as in the *Pyrenomycetes* (*cf.* p. 678). Otherwise they are in general agreement with the last group, and include crustaceous, foliose, and fruticose forms. There are only a





FRONDOSE AND FRUTICOSE LICHENS.

few genera of Pyrenolichenes, including *Verrucaria*, *Ephebe*, *Endocarpon*, and *Sphaerophorus*.

Basidiolichenes.—These occur only in tropical countries, and a number of genera were formerly distinguished, including *Cora*, *Dictyonema*, and *Laudatea*. *Cora pavonia*, the best-known form, consists of a greenish-yellow, fan-like, concentrically-striated thallus which produces its basidia on the under surface and contains *Chroococcus*-cells as its Alga; *Dictyonema*, on the other hand, consists of thin plates of rather felty consistency, in which the radiating character of the strands is very apparent; these delicate plates, blue-green in colour, stand out from the tree-branch to which they are attached. *Laudatea*, though resembling *Dictyonema*, is a crustaceous form. Both the latter forms have *Scytonema*-filaments as Algæ. Quite



Fig. 394.—*Lecanora esculenta*.

recently it has been shown by A. Möller, a naturalist who resided several years in Brazil, that all these supposed distinct Lichens are different growth-forms of one and the same Lichen. In addition to finding each of these forms in connection with the other—so that there is no doubt of their continuity—he found attached to the *Cora*-form the Fungus growing free from all trace of the Alga; this Fungus is one of the *Telephoræ* (cf. p. 688), and when it is supplied with *Chroococcus*-cells grows into the *Cora*-form. This seems to be the only well-ascertained instance in which a Lichen-fungus has been found growing wild independent of an Alga. The *Dictyonema*- and *Laudatea*-forms consist of the same Fungus growing upon *Scytonema* instead of *Chroococcus*. In the *Laudatea*-form the Alga seems to get the upper hand and to determine the growth of the thallus. *Cora* and its various growth-forms is certainly the most interesting, as it is also the most beautiful of all Lichens of which we have any knowledge.

Gasterolichenes.—A Lichen from the Gasteromycetes has also been recognized; it is a little, shortly-stalked, puff-ball-like form resembling a *Lycoperdon* (cf. p. 690). The Alga (a *Palmella*) is restricted to the peripheral portions of the Lichen, which is named *Emericella variegata*.

PHYLUM 3.—ARCHEGONIATÆ.

Plants showing a well-marked alternation of generations, that is of a sexual (oophyte) and an asexual generation (sporophyte). The latter reproduces the former by means of spores, the former the latter by means of egg-cells contained in archegonia. Fertilization is by means of spermatozoids which swim in water.

Class I.—BRYOPHYTA.

The sexual generation is in the greater number of cases a leafy shoot, arising from a branched, filamentous protonema. The asexual generation, which arises from the archegonium, is a stalked or sessile capsule containing spores; it is destitute of leaves, and never becomes independent of the oophyte.

Alliance XX.—Hepaticæ, Liverworts.

Oophyte nearly always dorsi-ventral; either thalloid or leafy. Protonema inconspicuous. Sporophyte a stalked or sessile capsule containing spores and usually elaters. A calyptra is not present.

Families: *Ricciaceæ*, *Marchantiaceæ*, *Anthocerotaceæ*, *Jungermanniaceæ*.

The oophyte generation in the first three families is a branched, ribbon-like, or lobed thallus (*cf.* fig. 196¹, p. 23), showing a distinction between its upper and lower surfaces, *i.e.* is dorsi-ventral. In the *Jungermanniaceæ* it is likewise thalloid in some forms, but in the great majority the oophyte has the form of a leafy shoot. The oophyte communicates with the substratum by means of rhizoids. The complete oophyte is preceded by an inconspicuous filamentous growth, the protonema, which arises directly from the spore, but this stage is not so well marked as in the Mosses. The sexual organs are borne usually in groups either in little depressions or upon special outgrowths of the thallus, or, in the leafy forms, are collected together into little "flowers" at the tips of the shoots or in the axils of the leaves. The female organs or archegonia are flask-shaped bodies with long necks, as in mosses. The egg-cell is contained in the enlarged basal portion, and on fertilization develops into the sporophyte or spore-capsule. The antheridia are delicate, stalked, oval or club-shaped bodies in which the 2-ciliate spermatozoids are developed. They resemble those of *Chara*, shown in fig. 374⁷ (p. 660). The spore-capsule develops within the archegonium; its lower portion (in all but the simplest cases) forming a "foot" or sucker which remains imbedded in the substance of the oophyte, its upper portion forming the capsule proper. In many forms, particularly in the *Jungermanniaceæ*, a stalk is developed between foot and capsule, so that the latter is ultimately hoisted up. The capsule does not burst through the archegonial wall until the spores are ripe, nor is a portion of the archegonium raised up as a cap on the capsule as happens in the Mosses. The capsule ultimately opens by splitting into valves. In nearly all cases *elaters* are present with the spores. They are long thread-like cells with spiral thickening of the wall, and as they dry become very hygroscopic and

contractile. They assist in the dispersal of the dust-like spores in many cases, though the details of their co-operation in this respect is not always the same. Before the ripening of the spores the elaters play an important part in the nutrition of the spores; they are sterile cells or filaments intermixed with the spores to which they conduct food-substances during their development. Attention has been already drawn to the brood-bodies or thallidia of Liverworts (*cf.* p. 24).

Ricciaceæ.—These are very simple little forms occurring in wet places or floating in water (*Riccia natans*) like a Duckweed. The thallus is lobed or it may be ribbon-like and branched. The sexual organs are sunk in little chambers on the upper surface of the thallus; antheridia and archegonia may occur on the same or on different individuals. The fertilized egg-cell is here entirely converted into a spore-capsule, *i.e.* a sheath inclosing spores. No elaters are present in this family,

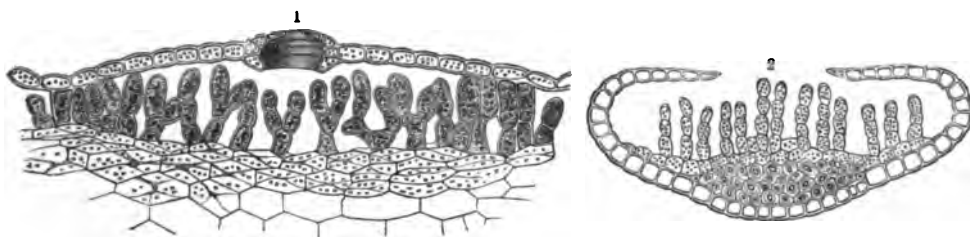


Fig. 395.

¹ Vertical section through an air-chamber of the Liverwort *Marchantia polymorpha* showing the stomate-like pore and the assimilating filaments. ² Transverse section of a leaf of a Moss, *Barbula aloides*, showing the projecting plates of cells. ¹×300; ²×330.

nor is there a sterile base or foot. The genus *Riccia* includes 107 species; there are 110 species in the whole family.

Marchantiaceæ.—The oophyte is a lobed band-like thallus (*cf.* fig. 196¹, p. 23) with marked dorsi-ventrality. On the upper surface are a number of chambers each opening to the exterior by a single stomate-like pore (*Marchantia*, fig. 395¹). These chambers are really excavations of the upper surface which become closed in save for the pores in question. From the floor of each chamber sprout filaments of chlorophyll-containing cells (fig. 395¹); these form the main assimilating tissue of the thallus. In *Marchantia* and *Lunularia* brood-bodies (or gemmæ) are budded off in cup-like receptacles (*cf.* fig. 196¹, p. 23). The sexual organs in this family are borne on special receptacles on the upper surface of the thallus. These may be either shield-like or stalked and umbrella-like (as in *Marchantia*, *Fegatella*, &c.). The male and female organs respectively occur on separate receptacles and are variously arranged. There are special sheathing structures associated with the archegonia. The sporophyte generation or sporogonium has a sterile base or foot which remains embedded in the archegonium. The spore-capsule is joined to the foot by a narrow, isthmus-like neck. The capsule opens by splitting into teeth. Elaters are present. Considerable variety is shown in this family in the form of the receptacles of the sexual organs.

165 species have been distinguished.

Anthocerotaceæ.—The oophyte has the form of a little lobed disc, in depressions of the surface of which the antheridia and archegonia are sunk. The sporogonium is long and cylindrical, and is invested in a circular sheath at its base. The spore-layer has the form of a hollow cylinder, leaving a sterile, central strand of tissue (the columella). Elaters are present amongst the spores, and serve as nutritive tissue for them rather than as instruments of dispersal. In this group

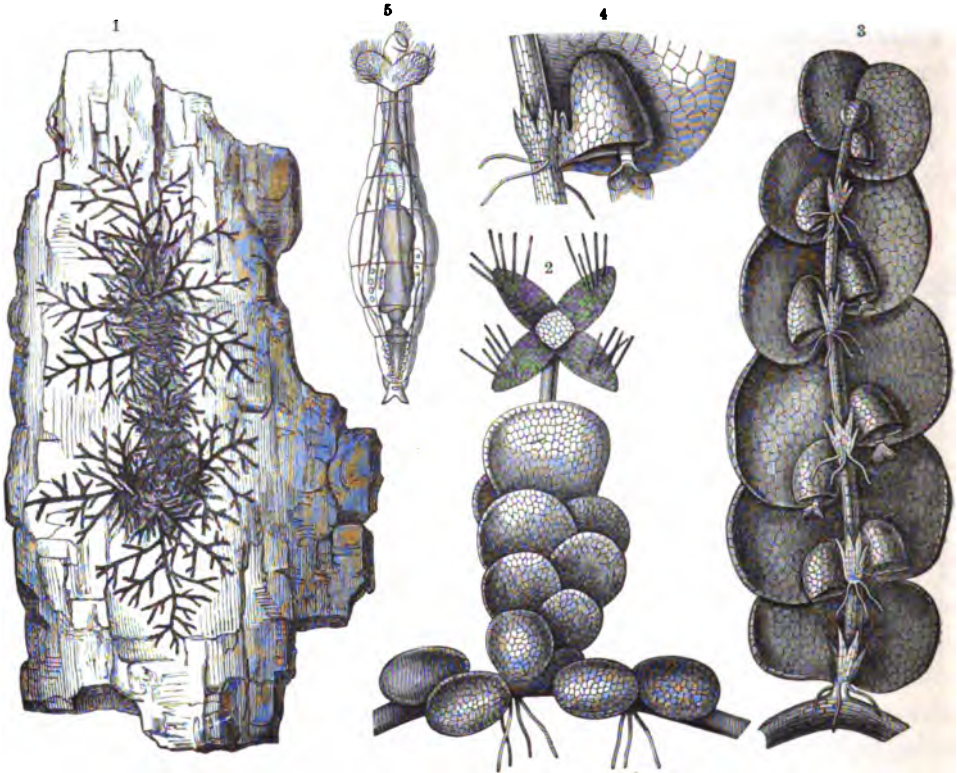


Fig. 396.—Jungermanniaceæ.

¹ *Frullania dilatata* growing on the bark of an *Acer*. ² A small portion of this plant enlarged; it shows the stalked spore-capsule burst into four valves; attached to the valves are the elaters. ³ A shoot of the same *Frullania* seen from the under side; at the base of each leaf is a little pitcher containing a Rotifer. The little toothed scales lying on the stem are the amphigastria. ⁴ A single pitcher and its contained Rotifer. ⁵ The Rotifer (*Callidina symbiotica*) removed from the pitcher. ¹ nat. size; ² $\times 20$; ³ $\times 25$; ⁴ $\times 80$; ⁵ $\times 100$.

—alone amongst the Liverworts—stomates occur upon the spore-capsule. It dehisces into two valves.

There are 103 species.

Jungermanniaceæ.—Include both thalloid forms, in which the oophyte generation has a general resemblance to that of a *Marchantia*, and creeping leafy forms (cf. fig. 396¹); the latter are by far the more numerous. The sporogonium in both cases consists of a long-stalked capsule which splits into four valves (fig. 396²). Elaters are present, often attached to the capsule-wall. The Jungermanniaceæ grow for the most part on damp earth, stones, and bark of trees.

The thalloid forms include the very common *Pellia*—like a *Marchantia*, with

long-stalked capsules inserted on its thallus—*Metzgeria*, branched and ribbon-like, the curious aquatic *Riella* with its spiral membrane (see fig. 366, p. 611), and the rather complex *Symphogyna* and *Pallavicinia* (chiefly tropical), with their creeping rhizomes and stalked fronds; these two forms, almost unique amongst the Liverworts, show a well-marked vascular system. The antheridia and archegonia are scattered over the surface of the thallus and not on stalked receptacles as in the Marchantiaceæ.

The leafy forms are very numerous and, as a rule, consist of branched axes which lie parallel to the substratum (e.g. *Frullania dilatata*, fig. 396¹). There are three rows of leaves, two towards the upper surface and one towards the lower. These ventral leaves, which are termed *amphigastria*, are tiny and scale-like (see fig. 396²), and sometimes are only represented by hairs. The archegonia are usually borne in little groups at the tips of the main or lateral shoots, and are inclosed in involucre. The antheridia occur in various positions. The sporogonium is always a long-stalked capsule as in the thalloid forms. Not a few of the leafy Jungermanniaceæ produce curious little appendages or "auricles" at the bases of their leaves, and these are often developed into little pitchers (fig. 396³). In other cases the amphigastria bear pitcher-like appendages of the same kind. These structures seem to be receptacles for the holding of water by capillarity against times of drought. In some forms Rotifers inhabit these pitchers (e.g. *Frullania dilatata*, figs. 396⁴ and 396⁵), but there is no evidence to show that the Liverwort uses their bodies as food like ordinary pitcher-plants, or that any special relations exist between the Rotifers and the Liverwort. The pitchers are not gall-structures directly produced by the Rotifer—they develop equally well with or without them. They are probably formed by the plant simply for storing water, and are found by Rotifers and other small animals to be convenient abiding-places.

There are more than 3500 species of Jungermanniaceæ

Alliance XXI.—Musci, Mosses.

The oophyte generation is the leafy moss-plant; it arises as a lateral bud from the simple and generally filamentous protonema. The sporogonium has a seta and spore-capsule, the latter usually possessing a central sterile mass of tissue, the columella. The upper portion of the archegonium is often raised as a calyptra by the elongating sporogonium.

Families: *Sphagnaceæ*, *Andreæaceæ*, *Archidiaceæ*, *Bryaceæ*.

Sphagnaceæ.—These are the Bog-mosses, and they include a single genus, *Sphagnum*. The form of the protonema here depends on whether the spore germinates in water or upon a solid substratum; in the former case it is branched and filamentous, in the latter it is a cellular expansion, not unlike a fern-prothallium. The leafy moss-plant arises by budding from the protonema, and is remarkable on account of its water-retaining properties. The character of the leaves has been already described and figured at vol. i. p. 219. The sexual organs arise on special

shoots at the apex of the plant (fig. 397¹⁴); these shoots are respectively male and female, and may occur on the same or on different plants. The antheridia are in the axils of the leaves of the male shoots, the archegonia in groups at the tips of the female shoots. The fertilized egg-cell develops into the sporogonium, the lower portion of which forms a large foot, whilst the upper part swells up into the spore-



Fig. 397 — Mosses.

¹ *Polytrichum commune*; the spore-capsule to the left is concealed by the cap (calyptra), that to the right is exposed. ² The same moss in an earlier stage of development. ³ Spore-capsule of *Polytrichum commune* with its lid. ⁴ The same after the falling away of the lid. ⁵ *Bryum caespitium*. ⁶ Spore-capsule of same with its calyptra. ⁷ The same after removal of the calyptra. ⁸ The same after removal of the lid, showing the teeth (peristome). ⁹ A portion of the peristome, enlarged. ¹⁰ Antheridia, archegonia, and paraphyses of *Bryum caespitium*. ¹¹ *Hylacomium splendens*. ¹² Spore-capsule of same. ¹³ *Andreaea rupestris* with burst spore-capsule. ¹⁴ *Sphagnum cymbifolium*; the spore-capsules are still intact in the left-hand specimen. ¹⁵ A single capsule of the same. ^{1, 3, 5, 11, 14}, natural size; ^{2, 4, 6, 7, 8, 12, 13, 15} $\times 5$; ^{9, 10} $\times 150$.

capsule. The spore-layer in the latter has the form of a hemispherical shell. Ultimately the archegonium is burst irregularly by the enlarging sporogonium, and the spores are set free by the removal of a circular lid at the summit.

In *Sphagnum* a true seta is not developed, the region between foot and capsule remaining quite short. The same result, however, is achieved by a considerable

elongation of the axis of the female shoot taking place in the region immediately below the group of archegonia. The capsule is thus hoisted up on a long stalk, though this stalk is no part of the sporogonium (*cf.* fig. 397¹⁵).

The remains of the Bog-mosses form an important constituent of peat.

Andreaeaceæ.—A small family, including the single genus, *Andreaea*. They are amongst the first settlers upon new and inhospitable rock-surfaces, and play an important part as soil-formers (*cf.* vol. i. p. 266). In them the mode of bursting of the spore-capsule is altogether peculiar amongst Mosses. Four longitudinal slits

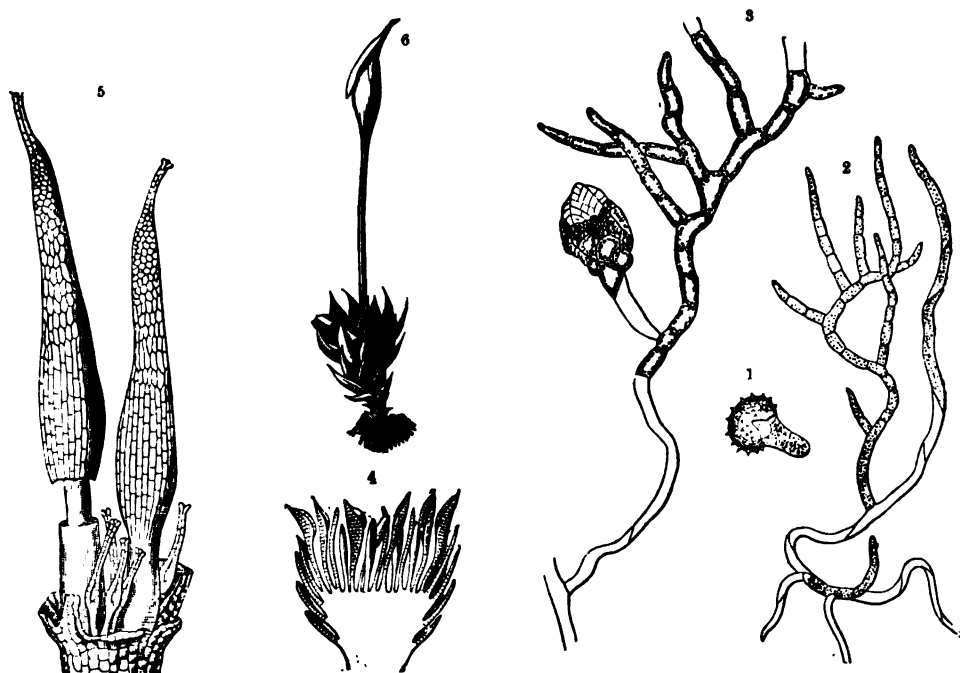


Fig. 398.—Mosses.

1 A germinating spore. 2 A Moss-protonema. 3 Protonema giving rise to a bud from which will arise a leafy moss-shoot. 4 Longitudinal section of the tip of a male shoot of a Moss; small, club-shaped antheridia are present between the scales. 5 Tip of a female shoot with archegonia; two of them containing sporogoniums have enlarged, and in the left-hand one of these two the upper part of the archegonium (calyptra) has been torn from the basal portion. 6 Leafy female shoot bearing a fully developed sporogonium; the calyptra is still in position. 1, 2, 3 $\times 850-400$; 4 $\times 15$; 5 $\times 80$; 6 $\times 5$.

arise in its wall, and the four valves remain attached to one another at the apex (*cf.* fig. 397¹⁵).

Bryaceæ.—This family includes the vast majority of the Mosses. The germinating spore produces a simple, branching, filamentous protonema (figs. 398¹ and 398²) on the surface of the ground, certain of its branches developing as colourless rhizoids and penetrating the substratum. From the protonema the ordinary leafy Moss-plant arises as a lateral bud (*cf.* fig. 398³). The curious properties of the protonema of the Luminous Moss (*Schistostega osmundacea*) have been already described (*cf.* vol. i. p. 385, and Pl. I. fig. p). The leafy shoots become rooted by the development of rhizoids from their lower extremities, and bear their leaves, as a rule, in three rows, though a slight twisting of the stem often disguises this fact.

The Luminous Moss just mentioned is an exception; in it the leaves are arranged in two rows (*cf.* fig. 399⁹). The leaves of Mosses are generally simple, and (unlike the *Jungermanniaceæ*) provided with midribs. In many of the *Polytrichæ*, and in *Barbula aloides*, &c. (*cf.* fig. 395²), the upper surface of the leaf bears longitudinal ridges of thin-walled chlorophyll-containing cells, thus adding to its assimilating and transpiring surface. The Moss-plant can propagate freely by means of brood-bodies and gemmæ. These sometimes take the form of modified leaves, sometimes of little stalked bodies on the leaves; occasionally they are collected together into little receptacles at the tips of the shoots, as in *Tetraphis* (*cf.* fig. 196, p. 23, where this and other cases are illustrated). The antheridia and archegonia are collected into little receptacles or "flowers" placed either at the tips of the shoots (in the *acrocarpous* Mosses, *cf.* figs. 397¹ and 398⁶), or laterally in the leaf-axils (in the *pleurocarpous* Mosses, *cf.* fig. 397¹¹). Occasionally both antheridia and archegonia are present together in the same "flower" (*cf.* fig. 397¹⁰), but more frequently they are in separate receptacles (*cf.* figs. 398⁴ and 398⁵). Mingled with them are sterile scales, the paraphyses. The structural details of the sexual organs and the mode of fertilization in Mosses has already been described (*cf.* pp. 64-66). After fertilization the egg-cell within the archegonium divides and enlarges, and gradually fashions itself into the sporogonium, the asexual generation of the Moss. For a time the archegonium stretches with the growing embryo, but sooner or later it is ruptured (*cf.* fig. 398⁵), and its upper portion raised aloft on the sporogonium as the calyptra. Sometimes the calyptra forms a closely-fitting cap, entirely investing the capsule as in *Polytrichum* (fig. 397¹), or it may be a little hood split down one side as in *Bryum* (figs. 397⁶ and 398⁶). After the raising of the calyptra by the elongation of the stalk or seta of the sporogonium the apex swells and develops into the capsule. Though in almost all cases the sporogonium consists of a capsule borne on a long smooth stalk (the seta), which is embedded below in the tissues of the female shoot of the Moss-plant, a very considerable amount of variety is met with in the structural details of the capsule itself. The seta may pass gradually into the capsule as in *Bryum* (fig. 397⁶), or there may be a bulb-like enlargement (apophysis) at the base of the capsule as in *Polytrichum* (fig. 397⁸), or this enlargement may attain considerable dimensions, exceeding the spore-producing part of the capsule, as in *Splachnum* (fig. 399). This apophysis is of importance as an assimilating and transpiring organ, and it is the only portion of the whole Moss which bears stomata. Within the capsule is the spore-layer. This has the form of a hollow cylinder surrounding a central sterile tissue, the columella. External to the spore-layer, and between it and the wall of the capsule, is a lacuna generally traversed by chlorophyll-containing filaments of cells. Above the spore-layer the columella expands into a mass of tissue, which forms the lid of the capsule (operculum, *cf.* figs. 397⁸ and 397⁷). At the periphery of the lid, where it abuts upon the wall of capsule, a ring of cells becomes marked out (the annulus); later, by the rupture of this ring the lid comes away, and the mouth of the capsule is guarded only by a set of teeth, the peristome (*cf.* figs. 397⁸, 397⁹, 399⁸, and 399⁸). By the time that the lid is ready to come

away the spores are ripe, and the columella, &c., have dried up and collapsed. The teeth of the peristome are exceedingly varied in pattern in the various genera of Mosses; typically there are two series of them forming an outer and an inner peristome (*cf.* fig. 397⁹), but they are differently thickened, fused, and divided, and one or even both series (e.g. *Gymnostomum*), may be absent. They are very hygroscopic, and their function will be alluded to later on when we are discussing the

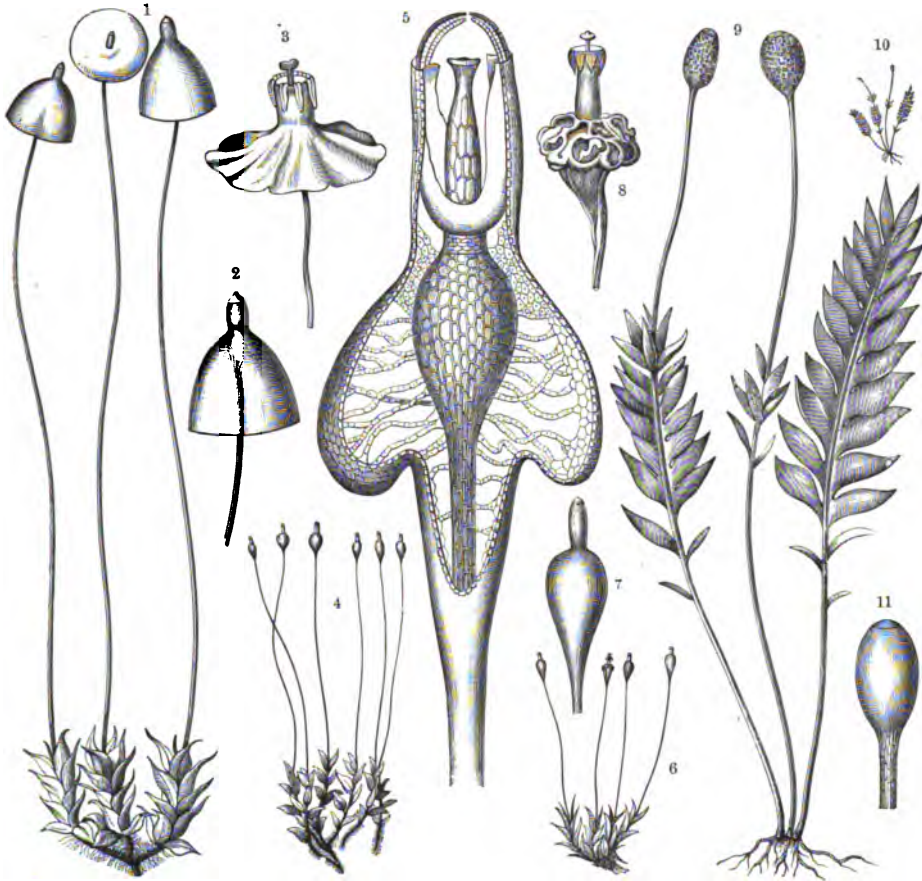


Fig. 399.—Spore-capsules of Mosses.

- ¹ *Splachnum luteum*. ² An unripe capsule of the same. ³ A ripe and open capsule of the same. ⁴ *Splachnum vasculosum*.
⁵ Longitudinal section of a ripe capsule of this moss, showing the large apophysis below containing lacunae, and traversed in the middle by the columella; above is the capsule proper with persistent columella, spore-sac, and peristome.
⁶ *Splachnum ampullaceum*. ⁷ An unripe capsule. ⁸ A ripe capsule of the same. ⁹ and ¹⁰ *Schistostega osmundacea*.
¹¹ A ripe capsule of the same. 1, 4, 6, 10 natural size; 3, 5 × 2; 7, 8, 9 × 10; 11 × 15; 2 × 100.

distribution of spores. In the Polytrichæ the peristome is not quite the same as in other Mosses. In this group the teeth are very numerous and quite short, and from their apices a membrane (the epiphragm) remains stretched after the fall of the lid (*cf.* fig. 397⁴). The spores here tumble out between the teeth.

The position of the sporogonium is of course determined by that of the female "flowers"; where these are terminal the sporogonium will be terminal (acrocarpous), similarly where lateral (pleurocarpous). The number of genera of Bryaceæ is so

numerous that it is hardly possible to mention even the most notable here. *Pontinialis* is of interest in being aquatic; *Splachnum* (cf. fig. 399) in having a very large apophysis and being saprophytic on animal excreta (cf. vol. i. p. 118). *Buabaukia aphylla* is an exceedingly simple form and vegetates in the protonema-stage. Leafy shoots are only formed in connection with sexual reproduction, and even then they are very rudimentary. This plant has been thought to be a primitive type of Moss.

Fossil Mosses are met with in Tertiary and more recent deposits.

Class II.—PTERIDOPHYTA, Vascular Cryptogama.

As in the Bryophyta, so here, a well-marked alternation of generations is exhibited in the life-history. Whilst in the Liverworts and Mosses the oophyte is the dominant stage ("the plant") here the sporophyte constitutes "the plant". The oophyte is a mere prothallium of simple nature, the sporophyte is a complex structure with root, stem, and leaves, and a well-marked vascular system. It becomes free from the prothallium at an early stage in development. The Pteridophyta contain the following alliances: *Filices*, *Hydropterides*, *Equisetales*, *Lycopodiales*.

The plant or sporophyte generation attains to a wide diversity of form in the Pteridophytes; thus, amongst the Ferns the stem is often short and bears a rosette of fronds, or is elongated and rhizome-like with leaves at intervals; in the Equisetales it is erect and jointed, and the leaves are reduced to toothed sheaths; and in many Lycopodiales the stem is procumbent, much-branched, and covered with simple scale-like leaves over the entire surface. Upon the leaves are borne the sporangia which contain the spores. The sporangia may be either scattered over ordinary leaves or on special leaves collected into cones. There is one feature connected with the spores that must be described here. Though in the Ferns and in many other Pteridophytes all the spores are of one kind and each gives rise to a prothallium bearing both archegonia and antheridia, there are Pteridophytes in the alliances Hydropterides and Lycopodiales in which two sorts of spores are produced. The latter are known as heterosporous, the former as homosporous. Where the plants are heterosporous the spores are of two sizes, and the larger ones (macrospores) are contained in fewer numbers in the sporangia than are the smaller ones (microspores). On germination the macrospore gives rise to a female prothallium only, the microspore to a male prothallium; i.e. growths which bear respectively archegonia and antheridia. The male prothallium is a very simple structure, and its part is played so soon as it has liberated its spermatozoids. The female prothallium having to nourish the young sporophyte for a while, until such time as it can live independently, is larger, and is usually well-provided with food-material.

Contrasting the Pteridophytes and Bryophytes, the Fern-plant corresponds to the sporogonium of the latter and the prothallium to the Moss-plant or Liverwort thallus. In the former the sporophyte, in the latter the oophyte generation is the more complex. But that a Fern-plant has been elaborated out of a Moss-sporogonium, or that the Fern-prothallium is a reduced or degraded Moss-plant, is exceed-

ingly improbable. It is more likely that the two groups have had a common origin, and have then developed along entirely different lines

Alliance XXII.—Filices, Ferns.

Families: *Hymenophyllaceæ*, *Polypodiaceæ*, *Cyatheaceæ*, *Gleicheniaceæ*, *Schizæaceæ*, *Marattiaceæ*, *Osmundaceæ*, *Ophioglossaceæ*.

With us for the most part Ferns have short underground stems bearing a rosette of leaves as in the Male Fern (*Aspidium Filix-mas*) and Hart's-Tongue Fern (*Scolopendrium vulgare*), or there may be an elongated horizontal underground rhizome, as the Bracken Fern (*Pteris aquilina*) and Polypody (*Polypodium vulgare*), the leaves being produced at intervals. In the tropics and sub-tropical regions, on the other hand, Tree Ferns are common. They belong mostly to the genera *Cyathea*, *Alsophila*, and *Dicksonia*. In these a considerable caudex is developed (cf. fig. 347, p. 473, and vol. i. p. 714), which is often enveloped in a perfect plexus of aerial roots. Many Ferns are epiphytic, especially in tropical forests (e.g. *Platyserium alcicorne*, fig. 349, p. 475); with us *Polypodium vulgare* is often met with enveloping the trunks and boughs of large trees. The tropical genus *Lygodium* is characterized by its climbing habit, the long rachis of its compound leaf twining like the stem of a twining plant. The view has been held, and is alluded to on p. 12, that the fronds of Ferns are not really leaves but modified stem-structures, the scaly structures that occur on the stem and fronds being regarded as the true leaves. It is sufficient to say that this view is not very widely held amongst Botanists, and that here the term leaf is used as synonymous with frond. Broadly speaking, Ferns love moist and shady habitats; they grow especially in woods and forests, and on humid rocks beside streams, &c. Generally their leaves are thin and delicate, and ill-adapted to withstand prolonged desiccation.

Borne on the leaves of Ferns are the sporangia, tiny capsules in which the spores are developed. The form of the sporangium and the arrangement of these bodies varies in the different families of Ferns—indeed the sporangia afford characters which are used for the grouping and classification of Ferns. In the commonest Ferns (belonging to the predominant family Polypodiaceæ) the sporangium resembles two watch-glasses placed together, the rim being occupied by a series of large, thick-walled cells (the annulus), and the whole mounted on a little stalk (cf. fig. 400¹⁴). In other families the stalk may be absent, the annulus incomplete, oblique, transverse or altogether wanting, &c., as will be pointed out in treating the several families. The sporangia are aggregated into clusters, the sori, and these are in many cases protected by little outgrowths of the leaf-surface (indusia) or under the infolded margins of the leaf. The form and arrangement of the sori and indusia provide the characters according to which the large family Polypodiaceæ is subdivided.

Hymenophyllaceæ.—The Filmy and Bristle Ferns. There is generally a rhizome which bears delicate fronds at intervals (cf. fig. 400²); the lamina of the

leaf is often only one cell thick, and stomata occur only in the genus *Loxosoma* (New Zealand). The other genera, *Hymenophyllum* (the filmy Fern) and *Trichomanes*, are both met with in Great Britain. The former is not uncommon on the rocks beside waterfalls, but the latter (*Trichomanes radicans*, the Killarney Fern) seems to be almost restricted to the south of Ireland. In this family the sporangia occur at the margins of the fronds on the excurrent veins (see fig. 400³). They are sessile, and the annulus is transverse, *i.e.* at right angles to the axis of the sporangium. The sorus is surrounded by an enclosure formed from the leaf-margin; this investment is cup-shaped in *Trichomanes* and bivalved in *Hymenophyllum*. Often in the former genus the axis on which the sporangia are inserted projects considerably from the cup—hence the name Bristle Fern. In this family the prothallium is unlike that of other ferns, being frequently filamentous and branched; the filaments often bear local expansions, upon which the archegonia are inserted.

There are about 200 species of Hymenophyllaceæ.

Polypodiaceæ.—By far the largest family of Ferns; indeed this family includes more than three times as many species as all the rest of the Pteridophytes together. Almost all our familiar European Ferns belong to it. The character which they all have in common is a stalked sporangium (fig. 400¹⁴), with vertical annulus. The distribution and form of the sori are exceedingly various. The Polypodiaceæ have been separated into the following tribes:—*Pterideæ*, *Aspidieæ*, *Asplenieæ*, *Davallieæ*, *Polypodieæ*, *Grammitideæ*, *Acrosticheæ*. In the *Pterideæ* the sori occur at the margin of the leaf; in the Bracken Fern (*Pteris aquilina*) the frond is much branched, and the sori are everywhere continuous on the pinnule-margin; they are covered in by an indusium derived from the margin; in the Maiden-hair Fern (*Adiantum Capillus-Veneris*) the tip of the pinnule is folded back over the sorus. In the *Aspidieæ* the sori are scattered, circular, and covered in by a circular or kidney-shaped indusium. *Aspidium Filix-mas* (the Male Fern) belongs to this tribe. The sorus is much elongated and linear in the *Asplenieæ*, and the indusium is inserted on one side of it (e.g. *Asplenium Ruta-muraria*, figs. 401⁶ and 401⁷). The Lady Fern (*Athyrium Filix-fœmina*), Hard Fern (*Blechnum*), Hart's-tongue (*Scolopendrium*), &c., are members of this tribe. In the *Davallieæ*, which include the large tropical genus *Davallia*, the sorus is near the margin, and inclosed in a pocket-like indusium. In the *Polypodieæ* the sori are circular and scattered over the under surface of the frond. There is no indusium (see fig. 400⁵). The *Grammitideæ* resemble the last-named in the absence of an indusium. The sori usually follow the veins, frequently forming very elegant reticulations on the under surface of the leaf, as in the tropical genus *Hemionitis*. The Gold and Silver Ferns (*Gym-nogramme*) belong to this tribe. In the *Acrosticheæ* the whole under surface is covered with sporangia, and there is no indusium. Examples are, *Rhipidopteris* (fig. 400⁴), *Platynerium* (fig. 349, p. 475), and *Acrostichum*.

Nearly 3000 species of Polypodiaceæ are known.

Cyatheaceæ.—This family includes the Tree-ferns (fig. 347, p. 473). The annulus of the sporangium is slightly oblique; it is only indifferently represented in

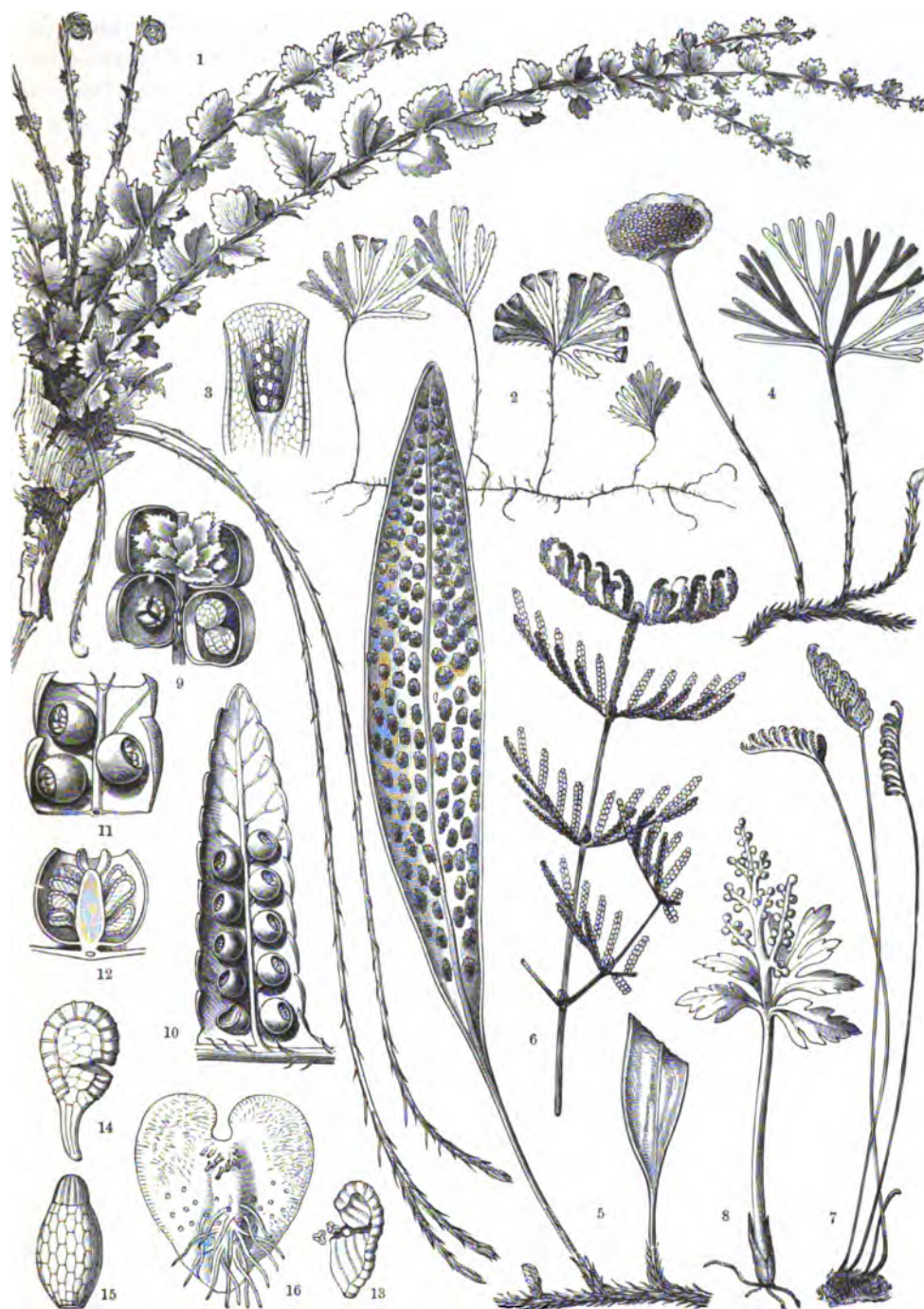


Fig. 400.—Various Ferns.

- 1 *Nephrolepis* *Duffii*. 2 *Trichomanes* *Lyallii*. 3 Sorus of the same fern, with cup-shaped investment seen in longitudinal section. 4 *Rhipidopteris* *peltata*. 5 *Polypodium* *serpens*. 6 Portion of frond of *Gleichenia* *alpina*. 7 *Schizaea* *fastuosa*. 8 *Botrychium* *lanceolatum*. 9 Under side of a fragment of the frond of *Gleichenia* *alpina*; above the sporangia are concealed by a tuft of scales, below they are exposed. 10 and 11 Fertile pinnule of *Cyathea* *elegans*. 12 Longitudinal section of a sorus of *Cyathea*. 13 Sporangium of *Cyathea*. 14 Sporangium of *Polypodium*. 15 Sporangium of *Schizaea*. 16 Under side of the prothallium of *Asplenium*. 1, 2, 4, 5, 6, 7, 8 natural size; 3, 9, 10, 11, 12, 13, 14, 15, 16 $\times 5-20$.

fig. 400¹³. In *Cyathea* (figs. 400^{10, 11, 12}) the indusium is cup-like, and closed until the spores are ripe. In *Dicksonia* the sorus is marginal, with bivalved indusium; in *Alsophila* the sori are scattered, and the indusium absent or rudimentary; in *Hemitelia* the indusium is scale-like, and situated on one side of the sorus. Of Cyatheaceæ about 200 species are known.

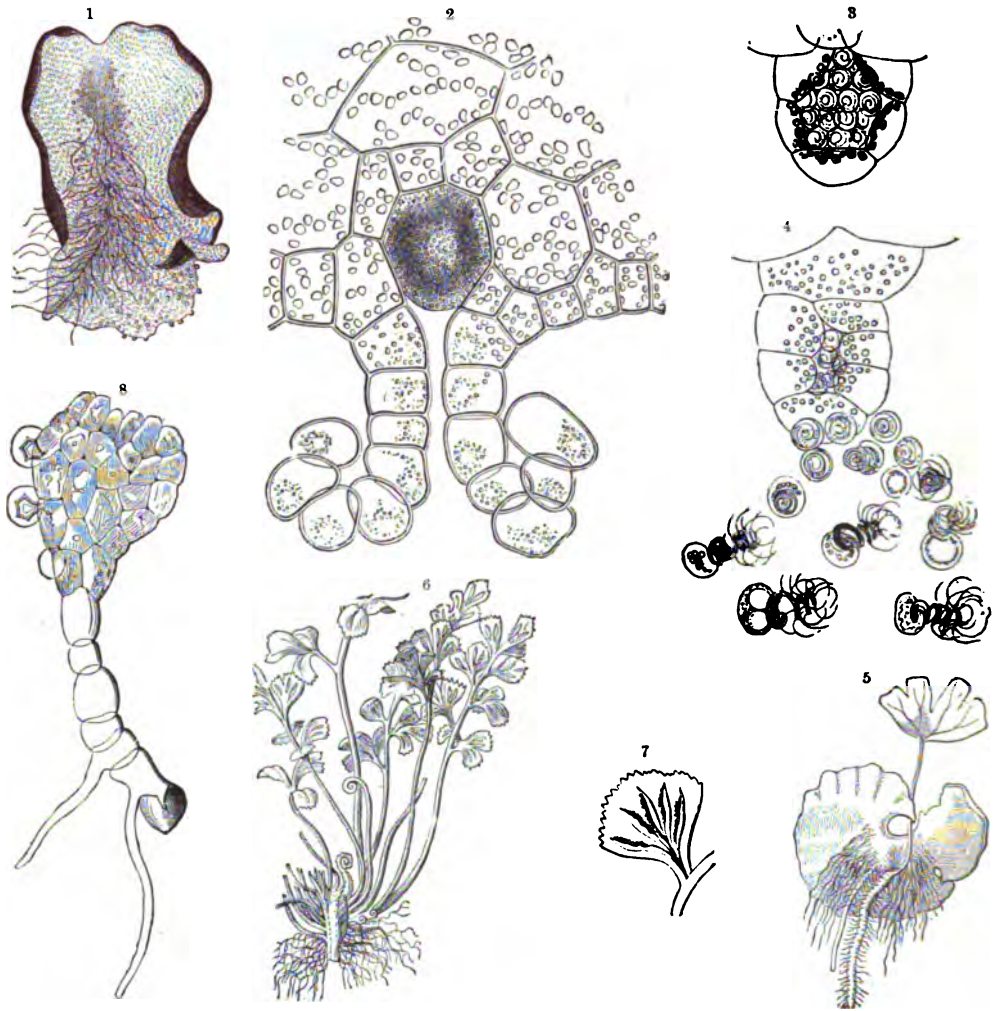


Fig. 401.—Life-history of a Fern.

¹ A Fern-prothallium seen from the under side. ² An archegonium in longitudinal section. ³ An antheridium. ⁴ Escape of spermatozoids from antheridium. ⁵ Young sporophyte with first leaf arising from the prothallium. ⁶ Complete sporophyte of *Asplenium Ruta-muraria*. ⁷ Under surface of pinnule of same, showing linear sori and lateral indusia. ⁸ A young prothallium arising from a spore; the spore is below. ⁹ natural size; ¹ $\times 8$; ², ³, ⁴ $\times 850$; ⁵ $\times 6$; ⁷ $\times 3$; ⁸ $\times 240$.

Gleicheniaceæ.—Mostly tropical forms. The sporangia have a transverse annulus, and are collected into little sori of 3 or 4 sporangia, often very closely packed (cf. figs. 400⁶, and 400⁹). The frond usually forks repeatedly. There is only one genus, *Gleichenia*, which has some 40 species.

Schizaceæ.—The members of this family are also for the most part tropical.

The sporangium is sessile, and the annulus is situated at the apex like a cap (*cf.* fig. 400¹⁵). In *Schizæa* (fig. 400⁷) the fertile pinnules bear two rows of sporangia partly sunk in little pockets; in the climbing fern *Lygodium* the leaflets bear little fertile spikes at the margin, and the sporangia are sunk completely in little pockets, one row on either side of the spike. In *Aneimia* the frond divides into two portions—a green vegetative portion, and several fertile branches whose ultimate ramifications are beset with naked sporangia. In habit *Aneimia* is not unlike a *Botrychium* (*cf.* fig. 400⁸). Of Schizæaceæ there are some 70 species.

Marattiaceæ.—Tropical Ferns, many of them attaining considerable dimensions. The fronds are distinguished by possessing a pair of stipules at their base. The sporangia are more bulky than in the families hitherto enumerated, and in *Angiopteris* are arranged in rows very close together, whilst in *Marattia*, *Kaulfussia*, &c., all the sporangia of each sorus are joined together into little button or bean-like bodies. There is no distinct annulus, though a little cap of cells possibly represents one. There are 25 existing species, but this family was much more abundant, than it now is, in palæozoic times; their remains are abundant in the Coal Measures.

Osmundaceæ.—Here also the sporangium is destitute of annulus, and possesses a little cap of cells in place of it. In *Osmunda regalis*, the Royal Fern, the upper pinnules of the frond alone produce sporangia, but in such quantity that their whole surface is covered with them; thus the tips stand out in marked contrast to the rest of the frond (hence the name “Flowering Fern”). The other genus of the family, *Todea*, resembles a Filmy Fern in the delicate texture of its leaves. There are only 11 species altogether.

Ophioglossaceæ.—A small family including the Adder’s-tongue (*Ophioglossum*) and Moonwort (*Botrychium*). The frond here divides into a sterile and a fertile portion, the latter seeming to arise from the base of the former. In the Adder’s-tongue the sterile portion is unlobed, and the fertile portion spicate, the sporangia being sunk in its substance. In the Moonwort (*cf.* fig. 400⁸) both parts are branched, the fertile portion resembling a panicle. The prothallium in this family is a little subterranean tuberous body. The origin from it of the sporophyte generation has not followed in any instance. There are twelve species of *Ophioglossaceæ*.

Alliance XXIII.—Hydropterides, Rhizocarps.

This alliance is nearly associated with the Filices and more particularly with the earlier rather than with the last-mentioned families of that alliance. All the genera are more or less aquatic in habit; but their distinctive feature is the fact that they are *heterosporous*, *i.e.* that some sporangia contain macrospores (one in each sporangium) the others microspores. The sporangia are collected into sori, which are inclosed by metamorphosed leaf-segments into little fruit-like bodies.

Families: *Salviniaceæ*, *Marsiliaceæ*.

All the members of the alliance agree in their aquatic habit and in being heterosporous. The macrosporangia are larger than the microsporangia, and contain one

big oval macrospore; the microspores are produced in numbers in the microsporangia. The macrospore, in addition to a hard wall, possesses an external gelatinous layer with stratified structure. On germination, the macrospore develops its (female) prothallium at one end, and, on the bursting of the spore-wall at the apex, this prothallium and the archegonia developed on its surface, are exposed. Of the contents of the spore, only a portion forms the prothallium, the rest remaining as a reserve mass. The microspores, which are usually embedded in mucilage, undergo several divisions (forming antheridia), and liberate spermatozoids, which fertilize

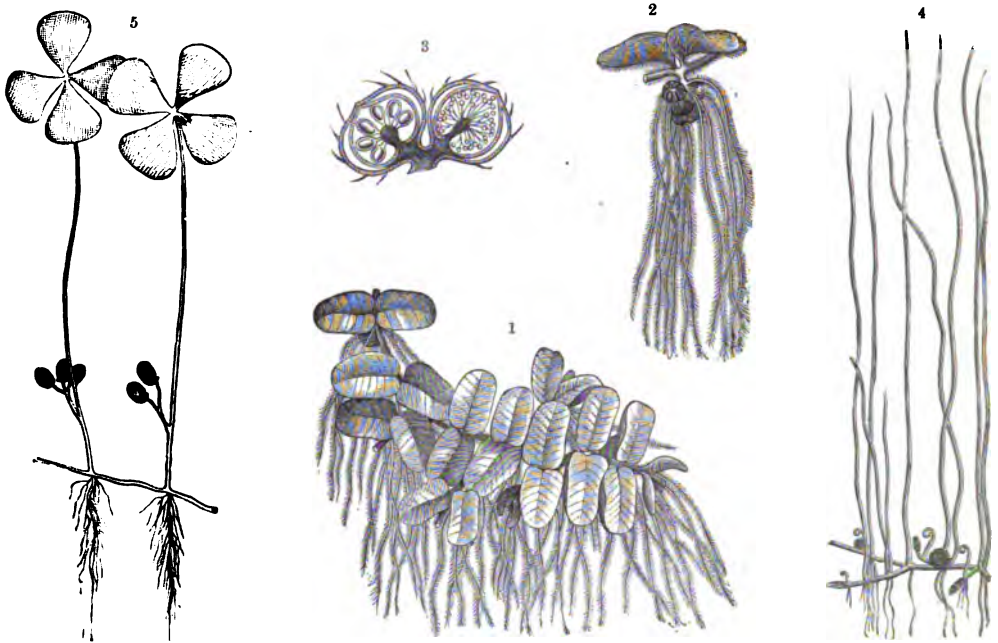


Fig. 402.—Hydropterides.

¹ *Salvinia natans*, showing the floating and submerged leaves. ² A portion of the same seen from the side, and showing the sporocarps at the base of the submerged leaves. ³ A section through two sporocarps of *Salvinia natans*; that to the left contains macrosporangia only, that to the right microsporangia. ⁴ *Ptilularia globulifera*; one or two sporocarps are shown at the base of the needle-like leaves. ⁵ *Marsilia quadrifolia*, showing sporocarps. ³ $\times 4$; the rest, natural size. (After Luerksen.)

the archegonia. From one of the archegonia the young sporophyte arises, and gradually develops into the adult form.

Salviniaceæ.—Include two genera, *Salvinia* and *Azolla*, both of which are floating plants. The former occurs in Southern Europe, the latter, though hardy in Europe, is a native of America, Australia, &c. *Salvinia* (figs. 402¹ and 402²) has a stem which lies horizontally on the water, and develops both floating and submerged leaves. The latter divide into numerous filaments, which hang down like tassels in the water (cf. fig. 402²). They are the absorptive organs of the plant, and play the part of roots. True roots, however, are wanting, even from the embryo. The sporangia are borne on these submerged leaves close to the point of attachment to the horizontal stem, generally in three groups or sori, each of which is inclosed in a cup-like upgrowth arising from the submerged leaf (cf. fig.

402³). The arrangement of the sori is not unlike those in *Trichomanes* (cf. fig. 400³), except that the cup is closed round the sorus. In each sorus occur only macrosporangia or microsporangia; but in each group of three sori usually one is different from the other two. Each sorus with its investment constitutes a sporocarp. The other genus, *Azolla*, resembles a floating, leafy *Jungermannia* (cf. fig. 396¹, p. 698); it is closely set with tiny leaves, and numerous true roots hang down into the water. The macrospores are provided with a floating apparatus and hooks; and the microspores which escape from their sporangia in packets have long barbed appendages, which become attached to the hooks of the macrospores. Thus the spermatozoids escape in the immediate neighbourhood of the female prothallia.

There are 9 species of Salviniaceæ.

Fossil residues occur in the tertiary formations.

Marsiliaceæ.—Containing the two genera, *Pilularia* and *Marsilia*. Both grow in marshy or inundated ground, and spread their rhizomes horizontally, attaching them by means of roots. The leaves in *Pilularia* (fig. 402⁴) are needle-like, and each bears at the base a very short branch which develops into a sporocarp. In *Marsilia* (fig. 402⁵) the leaves resemble those of *Oxalis*; near the base they give off a branch which may bear several bean-like sporocarps. The sporocarps in both these plants do not—as in the Salviniaceæ—consist of mere sori with an investment; but each is a leaf-segment in which a number of cavities develop (four in *Pilularia*, many in *Marsilia*), cavities which ultimately are quite cut off from the exterior, though they arise at first as pittings of the surface. In these cavities groups of sporangia arise—both macro- and microsporangia in each chamber. The sporocarp in this family is, therefore, in nature a leaf-lobe containing numbers of sporangial cavities, and of much greater complexity than in the Salviniaceæ. The sporocarps ultimately dehisce, the spores develop their prothallia, and fertilization takes place. There are 32 species of *Marsilia* and 3 of *Pilularia*. *P. Globulifera* alone is British. Fossils are found in tertiary formations.

Alliance XXIV.—Equisetales, Horsetails.

Possess jointed stems and small leaves inserted in whorls. The sporangia are produced on special leaves arranged in cones. All living examples are homosporous, but palæozoic forms include heterosporous genera.

Families: *Equisetaceæ*, *Calamariæ*.

The *Equisetaceæ* alone are represented by living plants, and include the solitary genus *Equisetum*, with about 40 species.

The habit of growth of the Equisetums is exceedingly characteristic. There is a branching underground rhizome from which erect ærial shoots are produced each year. From the nodes of the underground stems numerous fine roots arise (fig. 403²). The whole of the ærial shoot is green and assimilating, and the leaves are represented by funnel-shaped sheaths bearing teeth inserted at the nodes. The internodes are ribbed and the whole structure harsh to the touch, and often brittle owing

to the large amount of silica contained in the epidermal membranes. The early spring shoots of many species are unbranched and terminate in spore-bearing cones (e.g. *E. arvense*, fig. 403²), whilst later on other branching shoots arise which are sterile (fig. 403¹). In other cases the fertile shoots are also branched (fig. 403⁷).

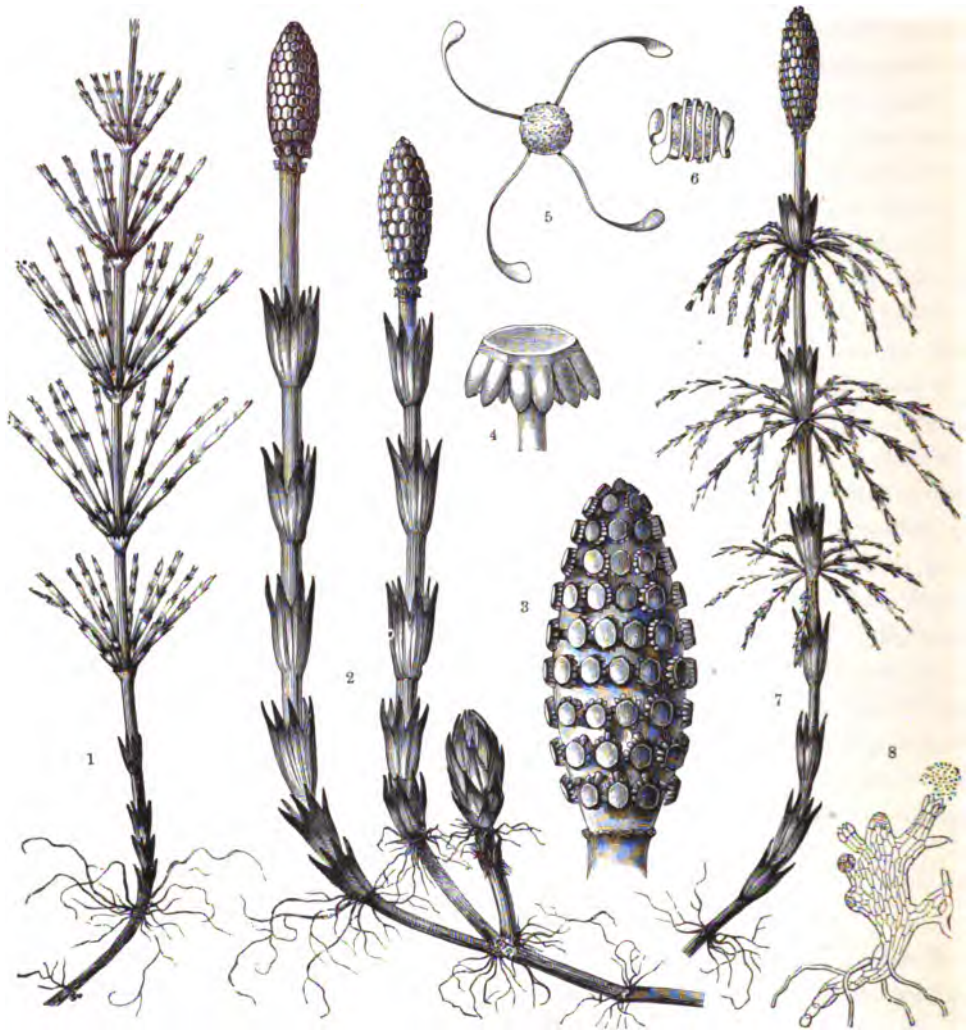


Fig. 403.—Equisetaceae.

¹ Summer sterile shoot of *Equisetum arvense*. ² Vernal, spore-bearing shoot of *Equisetum arvense*. ³ Fertile cone of the same. ⁴ A single sporangiferous scale (sporangophore) of the same. ⁵ and ⁶ Spores with "elaters" expanded and coiled. ⁷ *Equisetum sylvaticum* with cone. ⁸ Prothallium of a Horse-tail with antheridia. 1, 2, 7 natural size; 3 \times 3; 4 \times 6; 5, 6 \times 25; 8 \times 30.

The branches arise from the main axis in whorls at the base of the leaf-sheaths, and in most cases perforate the latter as they develop (fig. 403⁷). They repeat the structure of the main axis, save that they are smaller and have fewer teeth to their leaf-sheaths. *E. maximum*, common in this country in damp places, attains a height of two metres, and is the largest British representative of the group, but

E. giganteum (Tropical America) is stated to reach as much as ten metres. The Dutch Rush (*E. hiemale*) is largely used for polishing owing to the quantities of silica it contains. Characteristic of the stems of *Equisetums* is the large central air-space, which is only interrupted by diaphragms at the joints. Other spaces also occur associated with the vascular bundles and in the cortex, alternating with the bundles.

The spore-bearing cones (figs. 403^{2, 3, 7}) consist of stalked, shield-like leaves borne on the club-shaped termination of the axis. The scales bear numerous sporangia on their under surface (fig. 403⁴), and in these are the curious and characteristic spores. The wall of the spore is three-layered, and the outmost layer splits away from the one below it, forming four arms attached to the spore at one point (fig. 403⁵). These arms, termed elaters (not to be confused with the elaters of Liverworts, *cf.* p. 696) are extremely hygroscopic, and though at first coiled around the spores (fig. 403⁶) become extended as the spores dry, and as their humidity fluctuates contract and expand again. In this way the spores become entangled with one another and are distributed in groups, arm-in-arm. The importance of this circumstance appears to be as follows:—The spores, though all of one sort (*i.e.* homosporous), give rise to dioecious prothallia as a rule (*cf.* fig. 403⁸, representing a male prothallium); consequently it is of advantage for promoting fertilization that a number of prothallia should arise in the same neighbourhood. This result is achieved by a linking of the spores. The prothallia are richly lobed, but not unlike those of Ferns.

The *Calamariæ* are found as common fossil remains in the carboniferous formations. They include casts of the medullary cavity, impressions of the surface, and actual portions of the stems and cones in a petrified state. Many members of this family attained gigantic proportions, and their stems underwent a well-marked secondary increase in thickness. An examination of the cones shows that these former *Equisetales* possessed both micro- and macrospores.

Alliance XXV.—Lycopodiales, Club-mosses.

Forms usually with elongated, branching stems and small leaves distributed over them. The sporangia are borne on the upper surface of the leaf or in the leaf-axil; the fertile leaves are in many cases aggregated into cones. Both homosporous and heterosporous families occur.

Families: *Lycopodiaceæ*, *Psilotaceæ*, *Selaginellaceæ*, *Lepidodendraceæ*, *Sigillariaceæ*, *Isoëtaceæ*.

Whilst in the Filices and *Equisetales* several or many sporangia are present on the fertile leaves, in this alliance there is only one, and this is situated on the upper surface or in the leaf-axil. The sporangia in this group differ from those in many of the Filices (*e.g.* *Polypodiaceæ*) in being more massive and in having origin not from single epidermal cells, but from a row or group. Their form also is in many cases peculiar. The *Lycopodiaceæ* and *Psilotaceæ* are homosporous, the other families heterosporous. In the former the prothallia generally resemble those of Ferns, in

the latter their condition parallels that of the Hydropterides. Lepidodendraceæ and Sigillariaceæ are represented by fossil forms only.

Lycopodiaceæ.—The Club-mosses proper include some 100 species, distributed over various parts of the globe. The habit of a typical *Lycopodium* is indicated in the accompanying figure of *L. annotinum*, with its branching stem closely set with simple, scale-like leaves and terminal cones. The species common in mountain regions in this country are *L. clavatum*, *L. alpinum*, and *L. Selago*; *L. annotinum*



Fig. 404.—*Lycopodium annotinum*.

(fig. 404) is also met with. Of these *L. Selago* alone is devoid of cones, its sporangia occurring on the ordinary leaves. The sporangium is generally large and kidney-shaped, and is attached to the base of the upper side of the leaf (fig. 405⁴); its concavity is directed towards the axil of the leaf. Till recently the life-history of *Lycopodium* was unknown, as difficulty was experienced in causing the spores to germinate. It was first observed in certain tropical species, *L. cernuum* and others. In this species the prothallium has the form of a tiny tuberous body, with a lobed fringe on which the antheridia and archegonia are developed. The history of development of the sporophyte from the egg has been followed and is of some interest. In *L. cernuum* the young plant consists of a tubercle bearing a tuft of

leaves above. Gradually the stem elongates and the adult form is assumed. The special interest attaching to this stage is that it is characteristic of the mature *Phylloglossum* referred to below. It has been suggested that the last-named genus is a primitive form which retains as adult character what is but embryonic in *Lycopodium*.

The genus *Phylloglossum* (found in parts of Australia and New Zealand) possesses, in addition to its tubercle and tuft of leaves, a stalk which terminates in a cone of sporangium-bearing leaves. There is only a single species.

Psilotaceæ.—Includes two genera, *Psilotum* and *Tmesipteris*. *Psilotum* is tropical; it has delicate, angular, forking stems, and its leaves are reduced to tiny scales. It is rootless and grows epiphytically. Its sporangia are three-chambered and are borne on reduced leaves. Vegetative bulbils are frequently met with, especially on those shoots which grow upon the substratum. *Tmesipteris* is also an epiphyte (New Zealand and Australia). It has conspicuous, pointed leaves and long, trailing stems. The ordinary leaves are simple, but the fertile ones fork like a V, and the sporangium (which is two-chambered) is inserted on the upper surface at the junction of the V. The prothallial stage is not known in either of these genera.

Selaginellaceæ.—A family of some 300 to 400 species, which are in large part tropical, and all belong to the genus *Selaginella*. The shoots are forked and are dorsiventrally flattened. The leaves are borne in four rows—two rows of smaller overlapping leaves right and left of the median dorsal line, and two rather larger ones along the edges of the stem (cf. fig. 111¹, vol. i. p. 421). A very common species in the alpine regions of Europe is *Selaginella helvetica*, whilst *S. selaginoides* (= *S. spinosa*) is British. The last-named species, unlike the majority of Selaginellas, is not flattened, and its leaves are distributed around the stem as in a *Lycopodium*. A characteristic feature is the presence of a little tongue inserted in the median line of the upper surface of the leaf near its point of insertion; this is known as the *ligule*. The roots in most cases arise, not directly from the stem, but from special branches termed *rhizophores*. *Selaginella* is *heterosporous*. The sporangia are spherical and arise in the axils of the fertile leaves, which are collected into cones. The macrosporangia contain four macrospores, and the microsporangia numerous microspores. Both kinds of sporangia occur usually in one cone, the former below; or they may be in rows along the sides of the cones; or, finally, the two sorts of sporangia may be on different cones.

The product of germination of a microspore consists of a single, simple antheridium, containing spermatozoids, which are provided with two flagella attached to the pointed end. The macrospore produces a small, green female prothallium at one end (as in the Hydropterideæ, p. 710), whilst the rest of the spore, which here divides into large cells, serves as a reserve of food-material. The green portion bears the archegonia, and is exposed. After fertilization, an embryo arises, and gradually develops into the *Selaginella*-plant. The embryogeny presents various features of interest. In particular may be mentioned the production of a suspensor from that portion of the embryo which is towards the neck of the archegonium.

By the elongation of this suspensor the embryo proper is brought down into the aforementioned food-reserve, where it continues its development. This process is quite similar to the corresponding stage in Flowering Plants, where the suspensor is almost universally found.

Lepidodendraceæ.—This family, represented only by fossils from the Devonian and Carboniferous formations, consisted of large-growing Lycopod-like forms, with huge stems clad with linear leaves. They exhibit a secondary growth in thickness (wanting in recent Lycopods), and both micro- and macrospores were produced in the cones. Casts of *Lepidodendron*-stems bear characteristic rhomboidal areas corresponding to the leaf bases, and upon these the actual leaf-scars may be seen.

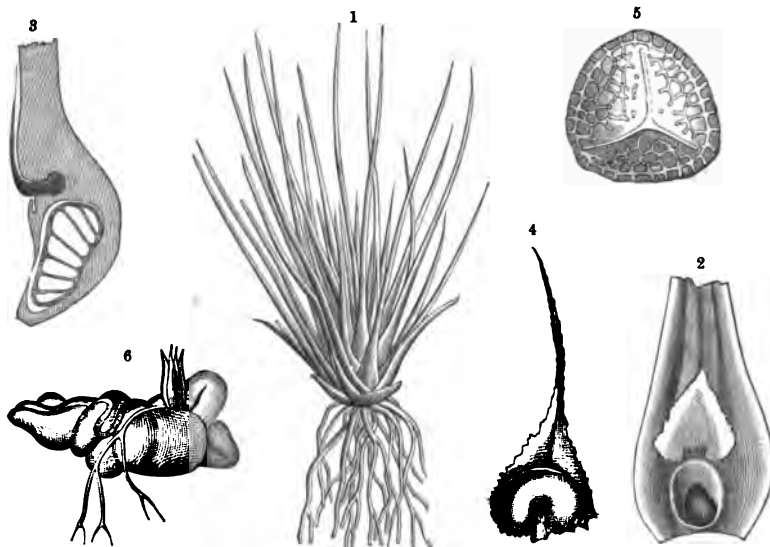


Fig. 406.—Lycopodiales.

¹ *Isoetes lacustris*. ² Expanded base of leaf showing the sporangium immersed in its socket and partly hidden by the velum and the ligule above. ³ Longitudinal section of base of leaf showing the strands crossing the sporangium and the insertion of the ligule. ⁴ Leaf from the cone of *Lycopodium clavatum* showing the kidney-shaped sporangium. ⁵ A single spore of *L. clavatum*. ⁶ Prothallium of *L. annotinum* with young plant attached. ¹ natural size; ², ³, ⁴, ⁵ $\times 10$; ⁶ $\times 100$. (After Luerssen.)

Sigillariaceæ.—Another family which flourished in carboniferous times. Like the *Lepidodendraceæ*, their stems are gigantic, thickened and scarred; they were also heterosporous. The marks on the stems are not rhomboidal, but shield-like, and they stand in vertical rows. The curious branching remains named *Stigmaria* constitute the root (or rhizome) of *Sigillaria*.

Isoëtaceæ.—Is a small family of aquatic mode of life, containing the single genus *Isoetes*, which is represented by some 50 species in various portions of the globe. Unlike the other members of the alliance Lycopodiales, *Isoetes* possesses an abbreviated stem, bearing a tuft of lance-like leaves. The common British species *Isoetes lacustris* may serve as type of the genus (fig. 405¹). It grows in quantity in the mud at the bottom of upland tarns and lakes in the northern parts of the country, and is attached by delicate roots which repeatedly fork. The very short

stem is furrowed on two sides, and from these furrows arise the roots. On rare occasions it is branched. From this stem arise numerous pointed leaves, which are slightly expanded below. Each leaf bears a sporangium, immersed in a socket on its upper surface (fig. 405²), and partly covering the sporangium a membrane, the velum. Immediately above the sporangium is the ligule, a little tongue-like emergence of unknown function (figs. 405² and 405³). Macrosporangia, containing several large macrospores, are generally found on the outer leaves, and microsporangia, with very numerous microspores, on the inner ones. The sporangia are crossed by strands of cells (*cf.* fig. 405³), termed trabeculæ, but these do not partition them into chambers. The germination of the spores presents certain resemblances to the same event in *Selaginella*, but it cannot be followed out in detail here.

An interesting feature in the structure of *Isoëtes* is the existence of a cambium-like zone in the stem just outside the central bundle-cylinder. This adds new tissue, both towards the inside and outside, but most abundantly towards the outside. This latter secondary cortex is parenchymatous, but in time it becomes corky. To its formation is due the curious form of the stem.

Though many species of *Isoëtes* live below water, others are terrestrial or semi-aquatic in habit. *I. lacustris*, as it grows at the bottom of a mountain tarn, is very similar in general appearance to two flowering-plants which affect the same situation, viz., *Lobelia Dortmanni* and *Littorella lacustris*; a closer inspection, however, will readily distinguish it.

Phylum IV.—PHANEROGAMIA, Flowering Plants

The general characters of Flowering Plants have been so fully dealt with in previous sections of this work that little more is needful here beyond a bare outline of the classification of their divisions and alliances.

The Phanerogamia are characterized by the production of seeds. The macrosporangia of heterosporous Archegoniatae are here represented by ovules, the macrospores by embryo-sacs, and the microspores by pollen-grains. The macrospore (embryo-sac) remains inside its sporangium (ovule), and here produces the reduced female prothallium (endosperm), which never has an independent existence. An egg-cell is formed within the embryo-sac, and this is fertilized by the pollen-tube which has arisen from a pollen-grain lodged upon a suitable receptive surface in the vicinity of the ovule. Ultimately, after the embryo has attained a certain differentiation, the whole macrosporangium, with contained embryo and food-material, comes away, and is known as the seed.

The oophyte or prothallial generation is thus suppressed as an independent stage in the life-cycle. The sporophyte, on the other hand, attains to a markedly more complex development than in the groups already treated. Fertilization of archegonia on free-growing prothallia by swimming spermatozoids is here replaced by a direct penetration of pollen-tubes to the ovules. To the "flower" also new duties are

allotted. In the Pteridophytes, fertile "cones" are frequently met with. They are assemblages of leaves bearing sporangia, and with the shedding of the spores accomplish their function. But in the Phanerogams it is not so. The stamens, having shed their pollen-grains (microspores), truly are done with. But the carpels which bear the ovules persist *in situ* until the ripening of the seed. And in the vast majority of Phanerogams, structures accessory to the stamens and carpels have become associated with the flower. These, forming the perianth, promote the transfer of pollen by attracting insects to the flowers in the innumerable ways already fully indicated in this volume. A minority of species depend on wind, and are destitute of attractive perianths. It is worthy of passing notice that wind-pollinated plants, though relatively few in species, are well represented in number of individuals in the various Floras of the globe. It is sufficient to instance the Conifers, Grasses and Sedges, Palms, Amentaceæ, and Urticaceæ.

The phylum Phanerogamia is divided into two sub-phyla, Gymnospermæ and Angiospermæ, which differ technically in that in the former the ovules are exposed on scales and receive the pollen-grains direct into the micropyle, whilst in the latter the ovules are borne in closed chambers, the ovaries, and the pollen is received on a special organ, the stigma

Sub-phylum A.—GYMNOSPERMÆ.

The pollen is received direct upon the nucellus of the ovule, whence the pollen-tube penetrates to the egg-cell. The embryo-sac (macrospore) is filled with the endosperm (prothallium) which bears archegonia sunk in its substance at that end which is directed towards the micropyle. In almost all cases the archegonia possess neck- and canal-cells in addition to the egg.

The phenomena accompanying fertilization and seed-production in the Gymnospermæ having been described at pp. 418 and 437, brief statements of the general external characters alone are given below.

The Gymnospermæ are divided into 3 Classes: Cycadales, Coniferæ, Gnetales.

Class I.—CYCADALES, Cycada.

Alliance XXVI.

Family: *Cycadaceæ*.

In habit the Cycads generally resemble the Tree-Ferns and Palms. They possess for the most part unbranched columnar stems terminating in a crown of large pinnate leaves. The surface of the stem is scarred with the bases of the fallen leaves, and recalls in appearance that of the fossil *Lepidodendrons* (*cf.* p. 716). In height Cycads do not exceed about 12 metres, and usually they do not attain even these dimensions. The flowers take the form of cones of closely aggregated scales, which vary in number from 30 to 600. The cones are respectively male and female, and



Fig. 408.—A group of *Cycas revoluta*. (From a photograph.)

are produced in close proximity to the apex of the plant, and sometimes (as in the female cone of *Cycas*) are actually terminal in position. The scales (stamens) of the male cones are usually boat- or shield-shaped, and bear very numerous pollen-sacs on their under surfaces, often aggregated into little groups or sori. The female cones are generally more massive than the male, and their scales (carpels) are shield-like or scale-like in form. In *Cycas revoluta* (cf. fig. 208¹, p. 74) the carpels more nearly resemble the foliage-leaves, and the ovules are borne in the position of leaflets. In other genera the number of ovules is restricted to two. Pollination is accomplished by the wind, and the ovule as it ripens develops a hard shell enveloped in a fleshy coat. The seed thus exhibits the superficial characters of a drupe (cf. p. 428).

Cycads are restricted to the warmer regions of the globe, and are especially characteristic of the Floras of Australia (*Macrozamia*, *Bowenia*, *Cycas*) and Central America (*Zamia*, *Ceratozamia*, *Dioon*). There are nearly 80 species, belonging to 9 genera, and they have mostly a somewhat restricted distribution. Fossil remains, from the Cretaceous onwards, are abundant, and show that in former times the Cycads formed a much more important constituent of the vegetation than at the present day.

A living collection of these interesting plants is cultivated in the Palm-house in Kew Gardens; it is exceedingly rich in forms, all the genera, and a large number of the species being represented.

Class II.—CONIFERÆ.

Alliance XXVII.

Families: *Araucariaceæ*, *Abietinæ*, *Taxodiæ*, *Cupressinæ*, *Taxaceæ*.

The Coniferæ, which include the various Pines, Firs, Junipers, Cypresses, and Yews, have characteristically branched stems. The leaves are usually linear and needle-like or scaly, rarely possessing an expanded lamina. The flowers are unisexual, and occasionally the sexes are on different individuals. In by far the larger number of Conifers the flowers are cone-like, i.e. aggregates of scales set upon a central axis and bearing respectively ovules and pollen-sacs. The stems of Conifers thicken up in the manner characteristic of Dicotyledons, but the secondary wood is composed entirely of tracheides (fibre-shaped elements), with peculiar bordered pits (cf. vol. i. figs. 10^{1, 2, 3}, p. 45); vessels are absent from it. In a great number of forms resin-ducts are present.

The families above given fall into two groups. The first of these includes the *Araucariaceæ*, *Abietinæ*, *Taxodiæ*, and *Cupressinæ*, and is characterized by the female flowers being cone-like. In the *Taxaceæ*, on the other hand, the female flowers are rarely in cones.

Araucariaceæ.—This group is familiar to everyone in the widely cultivated Chili Pine or "Monkey-puzzle" (*Araucaria imbricata*). The cones are made up of scales spirally arranged, and the ovules are solitary on the scales of the female

cones. The only other genus is *Agathis* (*Dammara*). These two genera include 14 species, distributed in the Southern Hemisphere only.

Abietineæ.—This family includes the majority of familiar Conifers of the Northern Hemisphere. They are distinguished by the fact that the scales of the female cones are divided into an upper ovule-bearing scale (the *ovuliferous scale*) and a lower subtending *bract scale*. The ovules are borne in pairs on the former,

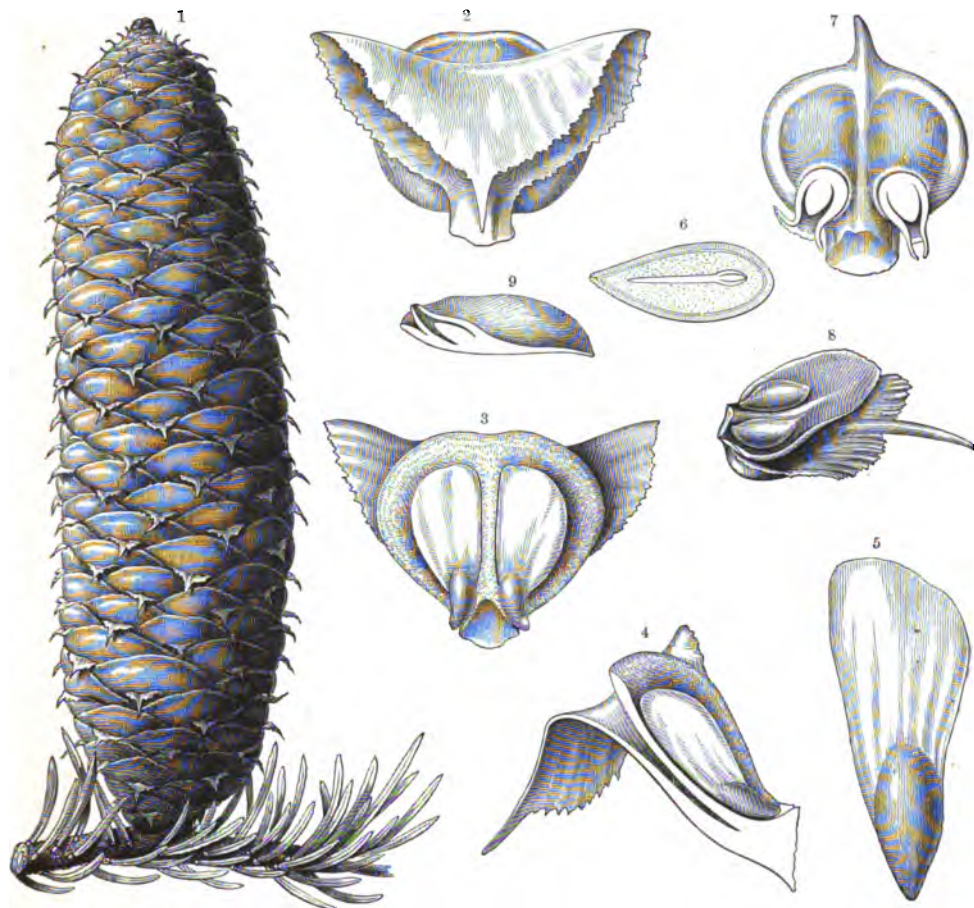


Fig. 407.—Female Cone and Scales in Abietineæ.

- 1 Cone of the Silver Fir (*Abies pectinata*). 2 Bract scale and ovuliferous scale of the same seen from the outside (the bract scale is pointed). 3 Ovuliferous scale of same seen from above, showing the two winged seeds, and the bract scale behind. 4 Longitudinal section of bract and ovuliferous scales, showing a seed *in situ* upon the latter. 5 A winged seed of the same. 6 Longitudinal section of the seed. 7 Ovuliferous scale of the Scotch Pine (*Pinus sylvestris*) seen from above; it bears two ovules. 8 Single ovuliferous scale of Larch (*Larix europæa*) showing two ovules on its surface and bract scale (with bristle) below it. 9 Longitudinal section of the ovuliferous scale of the Larch. 1 nat. size; the other figs. enlarged.

and on ripening into seeds are provided with membraneous wings in most cases. The relations of the parts of the scales and of the ovules are fully illustrated in the accompanying fig. 407. The pollen-grains also are characteristic, being in nearly all cases provided with two sac-like appendages which promote transit by wind (*cf.* fig. 217⁸, p. 98).

Included here are the Pine (*Pinus*), Cedar (*Cedrus*), Larch (*Larix*), and the

various kinds of Firs (*Abies* and *Picea*). All have needle leaves, but variously arranged. In *Pinus* the needles are borne in tufts of two (figs. 408⁴ and 408⁵) or three or five. The tufts are really short branches which arise in the axils of relatively

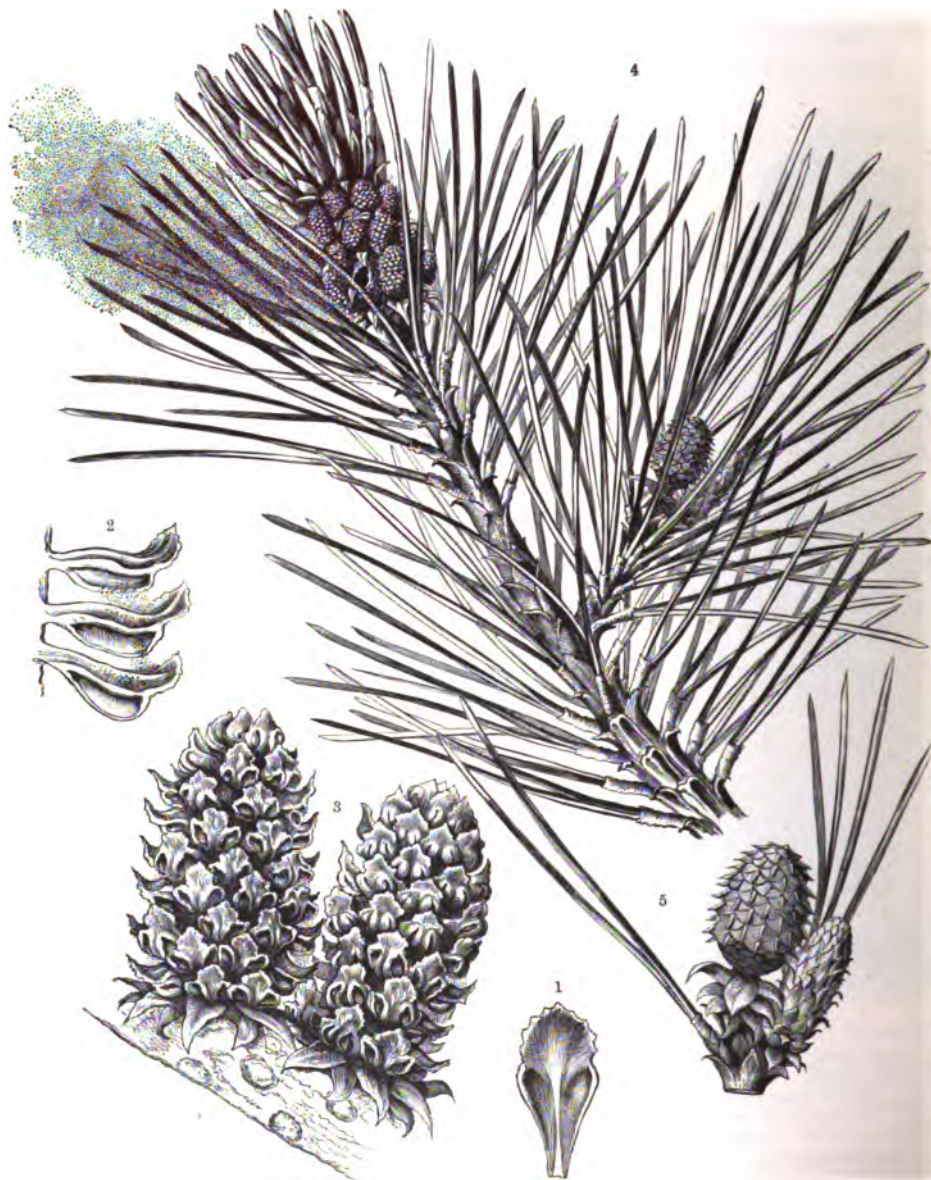


Fig. 408.—Mountain Pine (*Pinus Pumilio*).

¹ A single polliniferous scale (stamen) seen from above. ² Three polliniferous scales, one above the other, seen from the side. The pollen falling from each anther alights on the upper surface of the stamen next below. ³ Two spikes of polliniferous scales. ⁴ Branch with apical group of staminal flowers from which pollen is being discharged. ⁵ Female flower. ¹, ² $\times 10$; ³ $\times 8$; ⁴ $\times 2$; ⁵ natural size.

inconspicuous scales (cf. fig. 408⁵) and though these branches are produced plentifully, permanent long branches arise only at the yearly limits of growth. The



Scotch Pine (*Pinus sylvestris*).



Fig. 410.—The Arolla Pine (*Pinus Cembra*).

Pines may conveniently be divided into 2- and 3-leaved forms on the one hand, and 5-leaved on the other. The former agree in possessing cones of the type shown in fig. 337², p. 443, in which the ends of the ovuliferous scales visible at the surface of the cone are pyramidal, whilst the 5-leaved forms are without these terminal pyramids. Among the 2-leaved Pines (20 species) are included the Scotch Pine (*P. sylvestris*, fig. 409), the Stone Pine (*P. Pinea*), the Mountain Pine (*P. humilis* or *montana*, Plate X., and fig. 135, vol. i. p. 549), the Corsican and Aleppo or Shore Pines (*P. Laricio* and *P. halepensis*), and many others. Of the 16 species of 3-leaved Pines the majority are North American and Oriental. The Himalayan *P. longifolia* has needles nearly half a metre long, and the Californian *P. Coulteri* cones attaining a like length.

The 5-leaved forms include about 35 species, of which the beautiful Arolla Pine (*P. Cembra*, fig. 410) is a European, and the Weymouth Pine (*P. Strobus*) a North American example.

The genus *Cedrus* is represented by 3 forms, the Cedar of Lebanon (*C. Libani*), common in Asia Minor, the Deodar (*C. Deodara*) of the Himalayas, and the Atlas Cedar (*C. atlantica*). Some authorities regard these as but varieties of one species.

The Larch (*Larix*, cf. fig. 337¹, p. 443, and fig. 354, p. 483) bears its needles, which are deciduous, in tufts. The Firs which comprise the genera *Abies*, *Picea*, and *Tsuga*, differ from the Pines, &c., in that the leaves are borne directly upon the elongating branches. *Abies*, typified by the Silver Fir (*Abies pectinata*, cf. fig. 177, vol. i. p. 717), has erect cones (cf. fig. 407¹, p. 721), with conspicuous bract and ovuliferous scales; on ripening, the scales disarticulate from the axis of the cone. *Picea*, typified by the Spruce Fir (*Abies excelsa*, cf. fig. 105, vol. i. p. 415), has pendulous cones, with persistent scales, and, as a rule, the bract scale remains relatively short. *Tsuga Douglasii*, the Douglas Fir, and the Hemlock Firs are in certain respects intermediate between the Silver and Spruce Firs.

In all there are 120 species of Abietinæ distributed over the cooler parts of the Northern Hemisphere.

Taxodiceæ.—Are characterized by bearing more than two ovules on the scales of their cones. They include the two big *Sequoia*-species of North America, *S. gigantea*, the Wellingtonia or Californian Mammoth Tree, and *S. sempervirens*, the Red-wood, both of which attain to huge dimensions. *Taxodium distichum*, the so-called Deciduous Cypress, interesting on account of the curious knee-like roots which it produces above ground, *Cryptomeria japonica*, and *Sciadopithys verticillata*, the Umbrella Pine of Japan, all cultivated in this country as ornamental trees, are members of this group, which comprehends some 12 species in all.

Cupressineæ.—Are characterized by the fact that their cones have their scales in whorls, not spirals (cf. figs. 336⁶ and 336⁷ on p. 442, and figs. 337^{3, 4, 5}, p. 443). They include about 80 species, amongst them the Cypress (*Cupressus*), Arbor Vitæ (*Thuja*), *Juniperus*, and other ornamental genera.

Taxaceæ.—Have generally few scales in their female cones, and sometimes, as in *Taxus*, the Yew (cf. fig. 234, p. 145, and figs. 336^{1, 2, 3, 4, 5}, p. 442), the ovule is

terminal on a little shoot of its own. The seeds in this group are frequently embedded in a fleshy investment (often arillar in nature). Besides the Yews, there are included several peculiar Australasian forms, and the Maidenhair Tree, *Ginkgo biloba* (cf. fig. 337¹, p. 443). There are about 70 species of Taxaceæ.

Class III.—GNETALES.

Alliance XXVIII.

Family: *Gnetaceæ*.

This family which includes three very dissimilar genera, *Ephedra*, *Gnetum*, and *Welwitschia*, is by no means easy to define. In habit they are all of them quite unlike the members of the two preceding classes, but yet they fall under the sub-phylum Gymnospermæ in view of the fact that the pollen-grain has direct access to the nucellus of the ovule and from the resemblance (rather remote) which their ovules and embryogeny presents to other Gymnosperms. They agree amongst themselves in possessing flowers with perianths, vessels in their wood, and in the absence of resin-ducts from their tissues.

Ephedra is a good example of a switch-plant, having jointed assimilating shoots with little scale-like leaves at the nodes, as in *Casuarina* or *Equisetum*. The flowers which are borne in little clusters, are small and unisexual. The male flower consists of a central columnar stamen bearing 2–8 anthers and inclosed in a 2-leaved perianth. The female flower has an ovule with one integument and a little perianth. As the seed ripens the bracts around the flower become red and fleshy. There are some 20 species scattered over the warmer regions of the globe, including the Himalayas, Mediterranean, and Mexico.

Gnetum occurs as a liane or erect tree, and has expanded leaves like a Dicotyledon, in decussating pairs. The flowers occur in clustered, catkin-like spikes, on which they are arranged in whorls. The male flowers are very like those of *Ephedra*, the female have a central ovule with 2 integuments inclosed in a flask-shaped perianth. On ripening, the perianth becomes fleshy, and the outer integument of the ovule hardens to a stone. There are 15 species, distributed in the tropics.

Welwitschia mirabilis is a plant altogether unique. Discovered some thirty-five years ago by the botanical explorer Welwitsch, it has formed the subject of a classical monograph by Hooker. It occurs in the desert regions of West Tropical Africa (Angola, Damaraland, &c.). The stem is dwarf and top-shaped (cf. fig. 411), and may attain more than a metre in diameter. The summit of the plant never reaches far above the surface, and it bears two huge leathery leaves which sprawl on the sand on either hand. Actually 4 leaves are produced, the 2 cotyledons, which fall away whilst the plant is still quite young, and an additional pair placed at right angles to the cotyledons and persisting throughout the life of the plant. These 2 leaves grow continually at the base whilst their apical regions become



Fig. 411.—*Weinitschia mirabilis* in its natural surroundings (from a sketch by its discoverer).

tattered and broken. *Welwitschia*, once established, does not increase much in length but continually in thickness. From the edge of its disc, in the leaf-axils, arise branches which bear cones (cf. fig. 411). The male cones are small, and in the axils of their scales occur flowers consisting of 6 stamens united together into a sheath and surrounding a central structure which resembles an ovary, and contains a single ovule, which is, however, so far as is known, always abortive. This ovary-like structure is provided with a trumpet-like "stigma", and the occurrence of this remarkable structure in the male flowers points to the fact that the ancestors of this plant possessed hermaphrodite flowers. The fertile female flowers occur in the axils of the scales of other much larger cones, which become bright red in colour. Each flower consists of a perianth containing an ovule with 2 integuments, but although the inner of these integuments is very long, there is no stigma-like structure as in the male flower, and the pollen-grain reaches the nucellus. The developmental history of the ovule and embryo is exceedingly peculiar—as it is also in *Gnetum*—but we cannot enter into these matters here.

Sub-phylum B.—ANGIOSPERMÆ.

Ovules contained in closed ovaries. Pollen received on a specialized portion of the carpel known as the stigma, and fertilization achieved by means of pollen-tubes which penetrate hence to the ovule.

Angiosperms fall naturally into two classes, *Monocotyledones* and *Dicotyledones*.

Class I.—MONOCOTYLEDONES.

Includes Flowering Plants whose flowers typically have their parts arranged in whorls of three, embryos with one cotyledon, vascular bundles scattered through the stem and not thickened by a cambium, leaves usually parallel-veined.

The Monocotyledones may be divided into 6 alliances:—*Liliifloræ*, *Scitamineæ*, *Gynandræ*, *Fluviales*, *Spadicifloræ*, and *Glumifloræ*.

Alliance XXIX.—*Liliifloræ*.

Families: *Juncaceæ*, *Liliaceæ*, *Amaryllidaceæ*, *Iridaceæ*, *Dioscoreaceæ*, *Bromeliaceæ*, *Commelynaceæ*, *Pontederiaceæ*.

In this alliance the flowers are actinomorphic, and their parts arranged in whorls of three, i.e. two whorls constituting the perianth, two (or one) whorls of stamens, and a whorl of three carpels united together. This condition may be briefly represented by the following formula:— $P\ 3+3, A\ 3+3, G\ (3)$, in which P, A, and G stand for perianth, androecium, and gynæceum respectively. The bracket inclosing the number of carpels indicates that they are united (*syncarpous*). The ovary is 3-celled, and may be either superior or inferior; the seeds contain endosperm.

The *Liliifloræ* are for the most part herbs with perennial underground bulbs, corms, and rhizomes. In relatively few cases is a permanent above-ground system



Fig. 412.—Liliifloræ.

1 *Gagea lutea*. 2 *Galanthus nivalis*. 3 *Leucojum vernum*. 4 *Colchicum autumnale*, in flower and in fruit. 5 Section of capsule of *Colchicum*. 6 *Bulbocodium*. 7 *Convallaria majalis*. 8 Stigmas and stamens of an *Iris*.

produced. With the exception of the *Juncaceæ* the flowers are conspicuous and brightly coloured.

Juncaceæ.—Plants of grass-like habit with inconspicuous glumaceous perianth, six stamens, and superior ovary, which is 3- or 1-celled. Pollination by wind. Pollen-grains united into tetrads. Two well-known genera represented in this country are *Juncus* (with about 190 species), which includes the Rushes, and *Luzula*, the Woodrush. In all there are some 250 species of *Juncaceæ*.

Liliaceæ.—Herbaceous plants with bulbs, rhizomes, and corms, conspicuous



Fig. 413.—*Asphodelus ramosus* at Paestum (Southern Italy).

flowers with petaloid perianth, stamens 6, carpels 3, united, ovary 3-celled superior. Pollination by insects. Fruits are capsules or berries.

A number of tribes may be distinguished: (1) *Colchicaceæ* having usually extrorse anthers, septicidal capsules, and distinct styles. They include *Veratrum*, *Colchicum autumnale*, the Meadow Saffron (fig. 412⁴), which sends up its flowers in autumn, its leaves and ripening capsule next spring. *Bulbocodium* (fig. 412⁶) is frequent in cultivation. The Bog Asphodel (*Nartheceum*) also belongs to this tribe. (2) *Asphodeloideæ* include forms generally with rhizomes, rarely bulbs; anthers introrse, fruits capsular. Examples are *Asphodelus*, e.g. *A. ramosus* (fig. 413), which covers considerable tracts of country in southern Europe, forming regular plantations, and was supposed to carpet the Elysian fields; *Paradisea*





EUCALYPTUS GROVE AND GRASS-TREES IN AUSTRALIA.

Liliastrum, a beautiful alpine plant; *Heimerocallis*, the Day Lily; *Phormium tenax*, the New Zealand Flax (fig. 414), the leaves of which yield a valuable fibre; *Kniphofia*, whose dense spikes resemble a red-hot poker, cultivated in gardens; the Aloes and their allies, chiefly African, with a permanent aërial branch-system; finally, the Australian Grass-trees (e.g. *Xanthorrhœa hastilis*, shown in Plate XVI.), often a conspicuous feature in the landscape, and with its long spicate inflorescence sometimes attaining a height of 3 metres or more. This plant yields a valuable gum. (3) *Allioideæ*, usually bulbous, and having flowers



Fig. 414.—*Phormium tenax*, the New Zealand flax.

in umbels. They include the Onion tribe (*Allium*, cf. fig. 311, p. 386), of which *A. cepa* the Onion, *A. porrum* the Leek, *A. ascalonicum* the Shallot, *A. sativum* the Garlic, *A. schænoprasum* the Chive, and *A. scorodoprasum* the Rocambole, are cultivated. *Gagea* (fig. 412¹) also belongs to this group. (4) *Lilioideæ* have bulbs, anthers introrse, and loculicidal capsules. Styles generally united. They include numerous familiar and beautiful plants: *Lilium* (45 species), *Fritillaria* (40 species), *Erythronium* the Dog-tooth Violet, *Tulipa* (50 species), *Scilla*, *Hyacinthus*, *Ornithogalum* the Star of Bethlehem, *Muscari*, &c. (5) *Dracænoideæ* is an interesting tribe, as it includes the Yuccas and Dracænas, which possess a permanent aërial system, which exhibits what is very exceptional amongst Monocotyledons, a secondary thickening of the stem. *Dracæna Draco*, the Dragon-tree of

the Canaries, attains huge dimensions and a great age, and is altogether peculiar among this type of vegetation. The flowers of *Yucca* (fig. 415) are represented on p. 157, and its pollination described. (5) *Convallariaceæ* have rhizomes and berries.

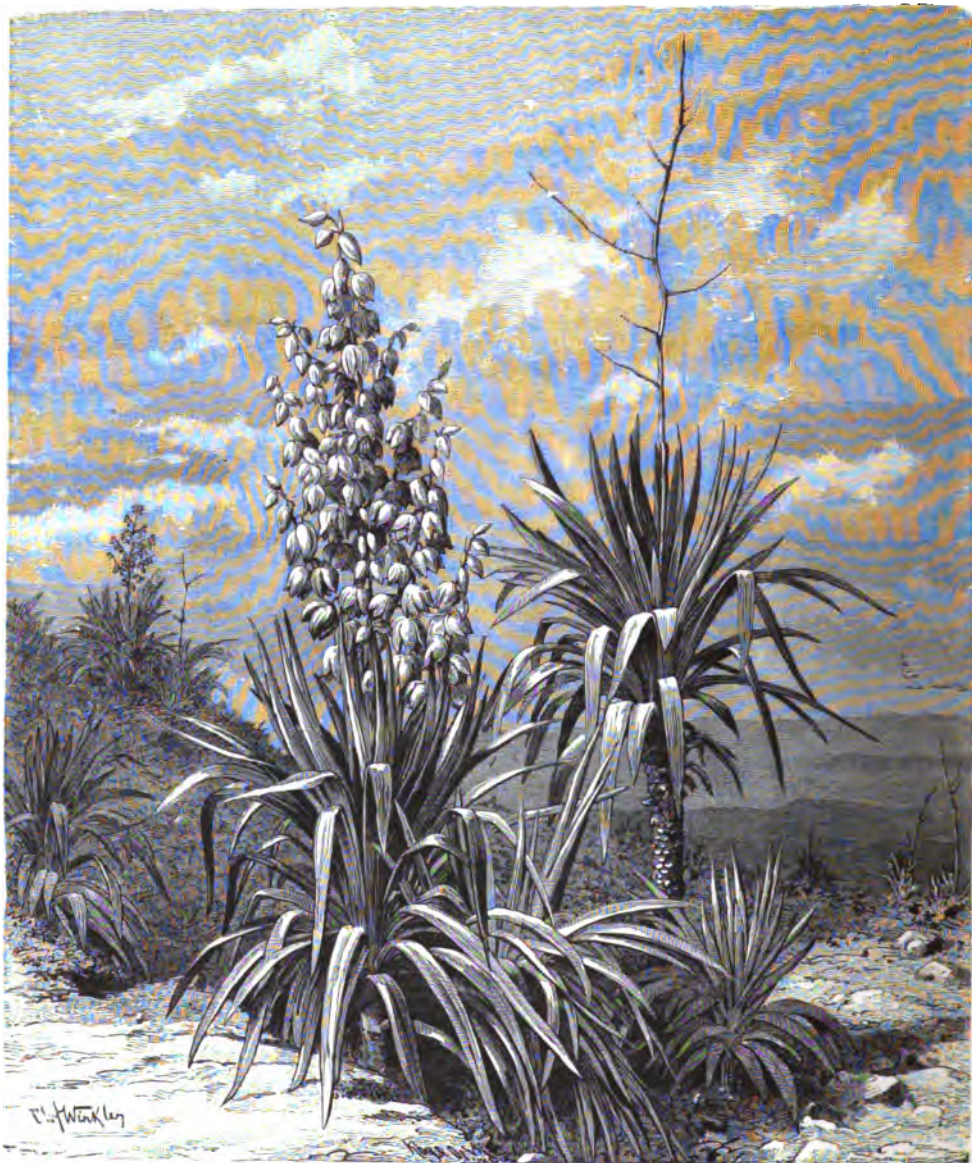


Fig. 415.—*Yucca gloriosa* (from a photograph).

They include *Convallaria majalis* the Lily of the Valley (fig. 412'), *Polygonatum*, *Aspidistra*, *Asparagus*, *Trillium*, *Ruscus* (vol. i. p. 333), and Herb Paris (*Paris quadrifolia*)—the last-named with the parts of its flowers in fours. (6) *Smilacoidæ*, which include climbers with net-veined leaves, e.g. *Smilax*.



Fig. 416. — *Echmea paniculata* (after Baillon).

Amaryllidaceae.—Resemble Liliaceae, but have inferior ovaries, and in many cases a corona to the perianth. They include the Snowdrop (*Galanthus nivalis*, fig. 412²), Snowflake (*Leucojum vernum*, fig. 412³), *Clivia*, *Amaryllis*, *Crinum*, *Narcissus* (with well-marked corona, fig. 248, p. 177); also, *Agave* and *Fourcroya* (cf. vol. i. p. 657).

Iridaceae.—Resemble Amaryllidaceae, except that they have three stamens only, with extrorse dehiscence. The stigmas are commonly very conspicuously developed. They include the Iris (figs. 412⁸ and 265), *Crocus* (fig. 223, p. 113), *Gladiolus*, the flowers of the last-named being slightly zygomorphic, and many others.

Bromeliaceae.—Possess distinct calyx and corolla. Ovary superior or inferior; fruit a berry or capsule. The family is tropical American, and very many of its members are epiphytes, showing interesting adaptations to this particular mode of life. The accompanying fig. 416 of the Peruvian *Echmea paniculata* gives a good idea of their mode of growth, with rosette of tough, leathery, sword-shaped leaves and dense, terminal inflorescence. Not infrequently the bracts which accompany the flowers are very brightly coloured. Two of the chief tribes of this family are *Tillandsiæ*, with capsular fruits, hairy seeds, and entire leaves; and *Bromeliæ*, with baccate fruits and toothed leaves (cf. fig. 416). The former includes the rather aberrant *Tillandsia usneoides* (cf. vol. i. p. 614), a widely-distributed American epiphyte which covers trees much in the same way as does the Lichen *Usnea barbata* in temperate zones. To the Bromeliæ belong numerous forms, including the *Echmea* figured here, and the Pine-apple (*Ananassa sativa*), the various portions of the fruiting-spikes of which become entirely succulent and confluent, forming the collective fruits referred to on p. 436.

The family includes about 400, and the whole alliance over 4000 species.

Alliance XXX.—*Scitamineæ*.

Families: *Musaceæ*, *Zingiberaceæ*, *Cannaceæ*, *Marantaceæ*.

This alliance includes tropical plants with rhizomes and large conspicuous leaves. In the flowers there is more or less reduction of the androecium, often combined with a production of petaloid staminodes. The ovary is inferior, and usually 3-celled, and the seeds, which are often inclosed in arils, have perisperm. The flowers are zygomorphic, or destitute of any sort of symmetry. As a whole this alliance is one of the most remarkable amongst the Monocotyledons.

Musaceæ.—The flowers of this family agree most nearly with those of typical Monocotyledons. Of the six stamens one only is absent or developed as a staminode. The flowers are zygomorphic. They include *Musa sapientum* (the Banana) and *M. paradisiaca* (the Plantain), widely cultivated for their fruits; *Strelitzia*, a remarkable South African genus, and *Ravenala Madagascariensis*, the Traveller's Tree, so named from the water which accumulates in the excavated sheaths of the leaf-stalks. This plant attains a height of 10 metres, and has a remarkable appearance (cf. fig. 417) owing to the fact that its huge leaves (amongst the largest in the



Fig. 417.—The Traveller's Tree (*Ravenala Madagascariensis*). After a drawing by Selleny.

vegetable kingdom) are borne in one plane. The fruits are large capsules, and the seeds are inclosed in arils with blue metallic lustre.

Zingiberaceæ.—One stamen, the posterior of the inner whorl, alone is fertile. The two others of this whorl are joined together to form a petaloid structure—the labellum. Here are included the Ginger (*Zingiber*), *Alpinia* (fig. 283¹, p. 289), and *Hedychium*, cultivated for the beauty of its flowers; also *Globba* and *Mantisia* (the Opera Girl) with flowers altogether remarkable; *M. saltatoria* presents some resemblance to a ballet-dancer, hence the name.

Cannaceæ.—Flowers altogether asymmetrical. The fertile stamen possesses only a half-anther and several petaloid staminodes are present forming the most conspicuous portion of the flower. *Canna indica*, the Indian-shot, and other species are much cultivated, and have given rise to numerous brilliantly-coloured hybrids.

Marantaceæ.—Have asymmetrical flowers and a fertile half-stamen only. The other stamens are modified into peculiar staminodes, and the family is nearly allied to *Cannaceæ*. Arrowroot is obtained from the rhizomes of species of *Maranta*.

The Scitamineæ includes about 600 species.

Alliance XXXI.—Gynandræ.

Families: *Orchidaceæ*, *Burmanniaceæ*.

Flowers with petaloid perianth and inferior ovary. The stamens reduced to one, two, or three, and generally united with the gynæceum to form a column (hence the name Gynandræ). The fruits are capsules, and the seeds exceedingly small and numerous.

Orchidaceæ.—After the Compositæ, the largest family of flowering plants, numbering some eight thousand or more species. Its members are chiefly tropical epiphytes, and their mode of life has received frequent mention in vol. i. Very characteristic of the Orchid flower is the median petal, developed as a labellum (cf. fig. 258¹ p. 227, and fig. 268² p. 255). The family may be divided into two divisions according to the number of stamens present.

Division 1. *Diandræ*.—Having usually two polliniferous stamens and a large and conspicuous staminode (which corresponds to the single fertile stamen of the *Monandræ*). The Lady's Slipper (*Cypripedium*, cf. figs. 267¹ and 267², p. 249, and description on p. 253) is the best-known representative of this division. A little group of plants, the *Apostasiaceæ*, is also included here. To it belongs *Neuwiedia*, with 3 fertile stamens (i.e. the two found in *Cypripedium* and the one which is represented by the staminode).

Division 2. *Monandræ*.—Includes the greater portion of the family, with one stamen only united with the gynæceum into the column and producing pollen in masses (pollen-masses). The single stamen is inserted above the stigmatic surface, from which it is separated by the rostellum, and is on that side of it which is away from the labellum, the usual alighting place for insects. The structure of the monandrous Orchid flower having been fully described and figured (pp. 253–257),

repetition is not needful here. The Monandræ may be divided into four tribes, the *Ophrydeæ*, *Neottieæ*, *Vandeæ*, and *Epidendreæ*.

The *Ophrydeæ* include most of the British and European Orchids, which are not



Fig. 418.—*Angraecum sesquipedale* epiphytic on a tree-trunk (Madagascar).

epiphytes but terrestrial, with swollen tuberous roots, including *Orchis*, *Ophrys*, *Gymnadenia*, *Habenaria*, and the South African *Disa*.

The *Neottieæ* also include some European forms, *Cephalanthera*, *Listera ovata* (the Twayblade), &c., and a series of colourless forms of saprophytic habit, which are destitute of foliage, including *Epipogium aphyllum* (fig. 257 ¹⁰, p. 226), *Neottia*

Nidus-avis (the Bird's Nest Orchid), and *Corallorhiza* (the Coral-root). To this tribe belongs the climbing Vanilla-orchid (*Vanilla planifolia*) the capsules of which yield the spice.

To the *Vandeeæ* and *Epidendreeæ* belong the numerous tropical epiphytes of which many genera are widely cultivated in greenhouses, such as *Lælia*, *Epidendrum*, *Cattleya*, *Masdevallia*, *Phajus*, *Catasetum*, (figs. 275^{1, 2, 3, 4, 5, 6, 7}, p. 269), *Stanhopea* (Plate XIII.), *Phalænopsis* (fig. 258¹, p. 227), *Odontoglossum*, (Plate XIII.), *Dendrobium* (fig. 275⁸), *Oncidium* (Plate XIII.), *Angræcum* (fig. 418), and many others besides (vol. i. Plate III.).

To give any idea of the enormous varieties of floral structure met with among the Orchids would require a whole volume. In this family of all others do we find adaptations to insect visits carried out on a gigantic scale, and in not a few cases mechanisms of singular beauty and delicacy. For full details Darwin's *Fertilization of Orchids* should be consulted.

Burmanniaceæ.—A small family of some 60 species, largely represented in Borneo and New Guinea, is of interest, as it seems to connect the highly specialized Orchidaceæ with more typical Monocotyledons like Amaryllidaceæ. They have curious flowers, with three or six stamens, and several of them are saprophytic.

Alliance XXXII.—Fluviales.

Families: *Potamogetaceæ*, *Naiadaceæ*, *Aponogetaceæ*, *Juncaginaceæ*, *Alismaceæ*, *Butomaceæ*, *Hydrocharidaceæ*.

This alliance includes a large number of aquatic forms, some with narrow, some with broad leaves. The gynæceum is superior, except in the Hydrocharitaceæ. The stamens and carpels show a tendency to an increased number as compared with typical Monocotyledons. On the other hand, many forms with reduced flowers occur. Endosperm is generally absent.

Potamogetaceæ.—Include chiefly submerged forms, some of which raise their inflorescences above the water-level, and are wind-pollinated (*Potamogeton*, fig. 419), whilst the others, including the Sea-grass (*Zostera marina*), *Zannichellia*, &c., are pollinated below the water. *Potamogeton* (Pondweed) is a large genus of some 50 species, met with in fresh and brackish water; *Zostera* grows on sandy shores between tide-levels, often forming extensive belts. The embryos in this family are peculiar. They consist of a much-thickened hypocotyl with a relatively small cotyledon inserted upon it. They are termed macropodous.

There are about 74 species of *Potamogetaceæ*.

Aponogetaceæ.—Contains two interesting genera, *Aponogeton* and *Ouvirandra*. The plant is submerged, and raises a spicate inflorescence (often forked) above the water. The flowers are imbedded in the spike, and consist of some 6 stamens and 3 free carpels, and a small number of perianth-segments. *Aponogeton distachus* is often cultivated in this country on account of its beautiful white flower-spikes. *Ouvirandra fenestralis* is the Lattice-leaf plant of Madagascar.

There are 15 species in all.

Alismaceæ.—Possess a 6-leaved perianth, and stamens with tendency to increase by division; carpels numerous. Here are included *Alisma Plantago*, the Water Plantain, and *Sagittaria sagittifolia*, the Arrowhead.

There are about 50 species.

Butomaceæ.—Includes *Butomus umbellatus*, the Flowering Rush, interesting from the fact that it bears ovules all over the internal surface of its carpels.

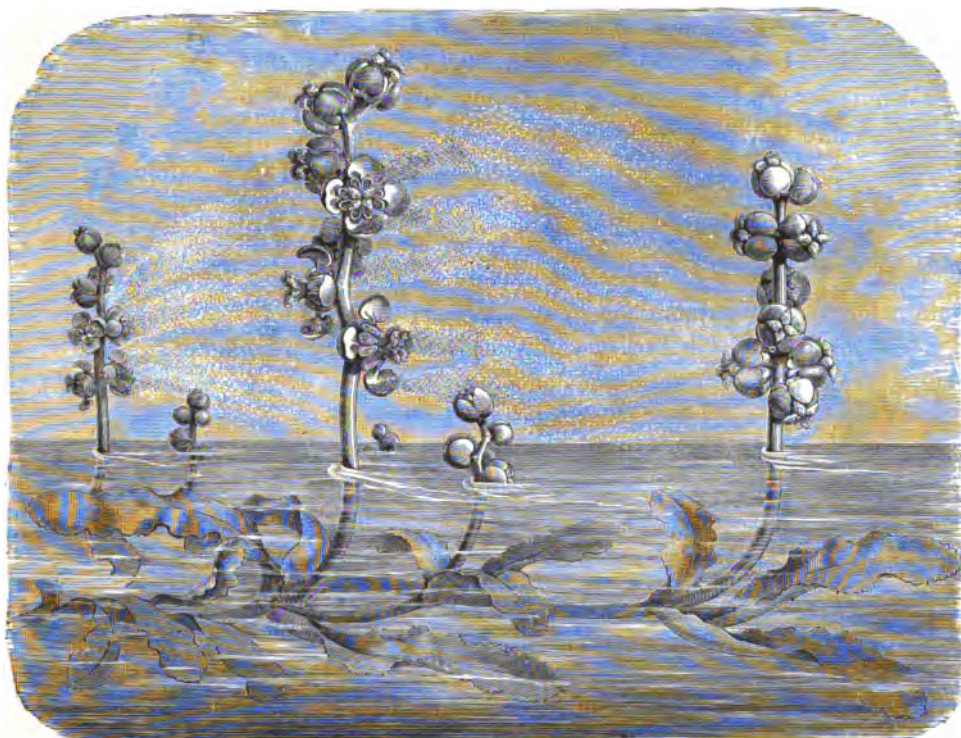


Fig. 419.—Curled Pondweed (*Potamogeton crispus*).

Hydrocharidaceæ.—Is distinguished from the foregoing families in that it includes submerged forms with inferior ovaries. The flowers are frequently unisexual, and in one form (*Halophila*) are pollinated under water, as in so many of the Potamogetaceæ. To this family belong *Vallisneria* (see fig. 155, vol. i. p. 667 and fig. 227, p. 132), *Elodea*, the American Water-weed (alluded to on p. 457), *Lagarosiphon* and *Enalus* (p. 133), *Stratiotes aloides*, the Water-soldier (vol. i. p. 552) and *Hydrocharis Morsus-ranæ*, the Frog-bit, with expanded floating leaves.

Contains about 60 species.

Alliance XXXIII.—*Spadicifloræ*.Families: *Palmaceæ*, *Aroideæ*.

Monocotyledons with small and usually unisexual flowers crowded on spikes or spadices, and inclosed in one or more conspicuous sheaths, the spathes. The ovaries are superior.

This alliance may be contrasted with the group *Compositæ* of Dicotyledons in which also the individual flowers are merged in dense crowded inflorescences which superficially resemble single flowers (cf. *Arum* and *Chrysanthemum*).

Palmaceæ.—Include plants with cylindrical, woody stems and tough fan-shaped or feather-like leaves of large dimensions having a plaited veneration. The flowers are borne in branched, fleshy spikes often inclosed in large sheathing leaves; they are hermaphrodite or unisexual and actinomorphic; the parts are arranged in threes, and are inconspicuous. The gynæceum consists of three carpels, each containing one seed. Stamens six, pollen dust-like. Fruits are berries, drupes, and nuts, and contain three, or by suppression, one seed. The endosperm is copious, and generally hard and stony. The majority of Palms possess upright, columnar caudices surmounted by a huge tuft of crowded leaves (cf. vol. i. p. 289, and Pl. VIII.). In several species the caudex attains a height of 30 metres, and in one (*Ceroxylon andicola*) 57 metres. The Climbing Palms have slender branched stems, and by the aid of the hooks on their leaves mount to the summit of trees and stretch like lianes from crown to crown (cf. vol. i. pp. 363, 675, and 676). The stems of these Palms reach a length of 150–200 metres, and yield the rotang cane. The opposite figure shows the interior of a forest penetrated by Climbing Palms and two natives rolling the stems into a coil. Old Palm-stems are either smooth and show the scars of the fallen leaves, or they still bear the disintegrated fragments of former foliage-leaves. Others again are armed with spiny girdles and scales. The leaves are folded in bud and undivided, and as they unfold they split along the creases, and the blade is divided pinnately or like a fan; we may distinguish between the feather-leaved and fan-leaved Palms. Often in young Palms the leaf splits at the apex into two pointed lobes only, as in *Areca disticha*, represented the foreground of fig. 420. The dimensions of Palm-leaves and the gigantic inflorescence of the Talipot Palm (*Corypha umbraculifera*) have already been alluded to (cf. vol. i. pp. 287 and 745). In *Oreodoxa regia* the sheathing base of the leaf attains a length of 2 metres and a half. The fruits of many species (e.g. *Chamærops excelsa*) are borne in grape-like bunches; in others they attain to great size and weight. The Double Cocoa-nut, the fruit of *Lodoicea Sechellarum*, is prominent in this respect (cf. p. 452).

Most Palms are eminently tropical in their distribution. Some genera are met with throughout the tropics, others (e.g. *Mauritia*, *Oreodoxa*, and *Iriarteia*) are confined to the New World; others again, as *Borassus* (*B. flabelliformis*, Pl. VIII.), *Raphia*, *Caryota*, and *Calamus* to the Old. *Chamærops humilis*, alone of the



Fig. 420.—Primeval forest in Ceylon with Climbing Palms (*Calamus*) and *Areca disticha* in foreground to the right. (Drawn from nature by v. Ranssonnet.)

Palms is indigenous to Europe; *Ceroxylon andicola* is found in the Andes growing at a height of 270 metres. Fossil remains are found in the formations of the secondary and tertiary formations. The number of living species is about 1100.

Aroideæ.—Perennial plants with tubers, rhizomes, and climbing stems which



Fig. 421.—Aroids.

¹ *Arum maculatum*. ² Spadix of *A. maculatum*, the spathe removed. ³ Fruiting spike of same. ⁴ Inflorescence of *Colocasia antiquorum*. ⁵ Basal portion of this inflorescence with part of spathe removed. ⁶ Ovary of *Colocasia antiquorum*. ⁷ The same in longitudinal section. ⁸ Columnar androecium of same. ⁹ *Aripopsis pellata*. ^{2, 5, 9} nat. size; ^{1, 3, 4} reduced; ^{6, 7, 8} enlarged.

generally bear large foliage-leaves. The flowers are borne on unbranched, fleshy spadices which are inclosed in large, expanded spathes (cf. figs. 421 ^{1, 4, 5, 9}); they are unisexual or hermaphrodite. The parts are inserted in whorls of 2 or 3; the perianth-members being inconspicuous and often absent. The androecium is very various. In *Colocasia antiquorum* (fig. 421 ⁸) it consists of a whorl of stamens



Fig 422.—*Raphidophora decurva* climbing in a primeval forest of the tropical Himalayas (from a photograph)



Fig. 423.—Climbing Aroids (*Philodendron pertusum* and *P. Imbe*) with cord-like aerial roots.

united into a single abbreviated column. Endosperm is present in the seeds. The tribe *Pistacæ* includes floating plants with leaves arranged in rosettes and propagating vegetatively by means of stolons. The *Aracæ*, of which the *Arum* (figs. 421^{1, 2, 3}) may be taken as a type, have subterranean tuberous stems, from which arise the leaves and spadices. Numerous representatives of other tribes, including *Ariopsis*, *Caladium*, *Dracontium*, and *Amorphophallus* have tubers. *Amorphophallus titanum*, the giant of this family, has a tuber 50 centimetres in diameter, and produces umbrella-like leaves on stalks 2-5 metres long and with segments in proportion. The inflorescence is a huge spadix some 2 metres high, encircled by a sheath of beautiful mottled green with purple lining and frilled edge. When this plant flowered at Kew in 1890 (for the first and as yet only time in captivity) it was one of the sensations of a London season. It is a native of Sumatra. A few species of *Montrichardia* (*M. linifera*) and *Philodendron* (*P. bipinnatifidum*) have erect cylindrical stems, whilst the Snake-root (*Calla palustris*) and Sweet Flag (*Acorus Calamus*) have creeping rhizomes. Many tropical Aroids belonging to the tribes *Monstereæ* and *Pothoideæ* climb up the stems of trees, fastening themselves by their aerial roots, and pass from crown to crown like lianes. The Himalayan *Raphidophora decursiva* (fig. 422) is an example of this type of growth. Many of these climbing Aroids send down pendent aerial roots into the humid air of the forest (fig. 423), and these not unfrequently reach the ground, take root, and become stretched taut.

The majority of Aroids are tropical, less than 10 per cent of the species being met with in temperate regions. *Acorus Calamus*, *Arum maculatum*, and *Calla palustris* reach the furthest north. The curious *Ariopsis peltata* (fig. 421⁹) occurs in the Himalayas to a height of 1600 metres.

There are about 900 species of living Aroids.

The *Lemnaceæ* is a little family of reduced forms allied to Aroidæ. The flowers are unisexual, and consist of a stamen and a carpel respectively. They are floating, flattened forms, and include *Lemna* (the Duckweed), and *Wolffia*, which is destitute of roots.

Associated with the Spadicifloræ are the Pandanaceæ, which include *Pandanus utilis*, the Screw Pine (cf. vol. i. fig. 186, p. 758); Cyclanthaceæ, climbing and palm-like; Sparganiaceæ and Typhaceæ, marsh plants, which include *Sparganium*, the Bur-reed, and *Typha*, the Bulrush.

Alliance XXXIV.—Glumifloræ.

Families: *Gramineæ* and *Cyperaceæ*.

This alliance, which includes some 6000 species, consists exclusively of Grasses and Sedges, forms with insignificant flowers destitute of coloured perianths and pollinated by wind.

Gramineæ.—Annual and perennial plants with upright, jointed haulms, and in the case of perennials, provided with creeping rhizomes. The leaves consist of an

undivided, linear, parallel-veined lamina (vol. i. fig. 150⁹), and a sheathing basal portion. At the junction of blade and sheath is inserted a little scale—the ligule. Flowers hermaphrodite and unisexual, arranged in spikelets (*cf.* fig. 231, p. 139). Perianth absent, its place being taken in many cases by 2 tiny scales, the *lodicules*, sometimes regarded as reduced perianth-leaves. Each flower is inclosed in a sheathing scale known as a *palea*, whilst outside this and subtending the flower is a bract-like structure, the *flowering glume*; this is often awned. Every flower is thus inclosed in a palea and flowering glume, whilst the whole spikelet is inclosed in a little 2-leaved involucre consisting of 2 outer glumes. The ovary bears 2 feathery stigmas, and contains a single ovule. The stamens are generally 3 in number, though variations are met with. The pollen is dust-like. Pollination has been fully described on pp. 140–142. The fruit or grain is indehiscent, and is known as a *caryopsis*. The seed contains a floury endosperm, and an embryo placed at one side (*cf.* vol. i. figs. 141^{3, 4, 5}, p. 599). The internodes of the haulm are in *Zea*, *Andropogon*, *Panicum*, &c., filled with pith; in the majority of Grasses they are hollowed. The Bamboos and numerous other tropical Grasses have upright perennial stems, and form an arborescent vegetation (*cf.* vol. i. p. 713). Bamboos attain a height of 25 metres and a diameter of nearly half a metre. But the majority of Grasses produce new haulms each year from their subterranean rhizomes, and these die down at the end of the season. The female flowers of the Maize (*Zea Mais*) are borne on thick spadices (cobs) inclosed in sheathing bracts. Grasses are widely distributed over the globe, the tropics being richer in species than the temperate regions, but poorer in individuals. Grasses are found extending into arctic and alpine regions to the extreme limits of phanerogamic vegetation; thus in the Alps *Poa laca* has been found at an elevation of 3000 metres. The Bamboos are tropical and sub-tropical; in the Steppes certain Grasses are very predominant, *e.g.* the genera *Stipa* and *Festuca* (*cf.* Plate VI. vol. i. p. 616). In moist, temperate climates, Grasses form a continuous carpet, the basis of meadow land. In marshy places and by river banks reed-like Grasses occur in great quantities (*e.g.* *Phragmites communis*).

Gramineæ number about 3500 species.

Cyperaceæ.—Annual and perennial plants with upright, haulm-like stems, jointed below and with long upmost segment. The leaves much resemble those of Gramineæ, but the ligule is wanting. Flowers hermaphrodite and unisexual, aggregated into spikelets, inclosed in bract-like scales. Perianth absent, or represented by scales, bristles, or hairs. The ovary is 2- or 3-carpellary. Stamens in one or two whorls of 3 each; pollen dust-like, pollination by wind. The seed contains endosperm. In the Scirpæ the leaf-blades are frequently obsolete, and assimilation is carried on by the stems. *Scirpus lacustris* reaches a height of 1, *Papyrus antiquorum* (or *Cyperus Papyrus*, fig. 424) of 3 metres and a diameter of 10 centimetres. The pith of the larger flowering stems of this plant cut into thin strips, united together by narrowly overlapping margins, and then crossed under pressure by a similar arrangement of strips at right angles, constituted the papyrus of



Fig. 42A.—*Papyrus antiquorum* in the Upper Nile.

antiquity; it grows in the Upper Nile, Syria, Palestine, &c. The stem of *Papyrus* bears at the summit an umbel-like tuft of filamentous branches, upon which the inflorescences arise. *Cyperaceæ* grow for the most part on damp moors, and by the banks of streams and lakes, and in mountain regions. Many of them are social forms, noteworthy in this respect being *Carex stricta*, which forms hummocks in marshy places, standing up above the water, often thousands together. Several Sedges, e.g. *Carex sempervirens* and *C. firma*, contribute largely to the turfy carpet of alpine slopes (cf. Plate XII.).

The family is distributed over the whole world. *Carex*, *Eriophorum*, and *Scirpus* are found especially in cooler and northern zones; *Cyperus* and *Papyrus* in warmer regions. About 2500 species are known.

Class II.—DICOTYLEDONES.

Flowering Plants whose flowers typically have their parts arranged in whorls of four or five, embryos with two cotyledons, vascular bundles arranged in a ring and undergoing a secondary increase in thickness, leaves more complex than in Monocotyledones and usually reticulately veined.

The Dicotyledones may be divided into three Sub-classes: *Monochlamydeæ*, *Monopetalæ*, and *Polypetalæ*. The *Monochlamydeæ* have a simple perianth, or in some cases the perianth may be wanting. The Sub-class is an artificial one, as it includes forms whose ancestors probably possessed a double perianth and others which are primitively simple. The *Monopetalæ* and *Polypetalæ* possess both calyx and corolla; in the former the parts of the corolla are united together, in the latter free.

Sub-class I.—MONOCHLAMYDEÆ.

Alliance XXXV.—Centrospermeæ.

Families: *Piperaceæ*, *Polygonaceæ*, *Cynocrambaceæ*, *Urticaceæ*, *Chenopodiaceæ*, *Nyctaginaceæ*, *Amaranthaceæ*, *Paronychiaceæ*, *Caryophyllaceæ*.

Annual or perennial herbs, shrubs, and trees. Venation of the leaf-blades palmate or pinnate. Flowers solitary or in cymes; the cymes arranged in fascicles, glomerules, or spikes. Flowers actinomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious. Floral-leaves in one or two whorls; all sepaloid, all petaloid, or (in a few cases) the outer whorl sepaloid and the inner whorl petaloid. Where a corolla is developed the petals are free. In the case of diœcious flowers there is no difference between the male and the female flowers in respect of the development of floral-leaves. The ovary is superior; 1-5-carpellary, unilocular. The ovules are borne in the centre of the ovary on a stalk which rises from the bottom of the ovary, and is sometimes long, sometimes short. Stamens 1-30, arranged in one or two whorls, the outer ones inserted in front of the sepals or sepaloid perianth segments. Fruit an achene, capsule, or berry. The seed contains an abundant farinaceous or mucilaginous endosperm. Cotyledons not thickened.

The Centrospermæ are extremely rich in inorganic salts, and in the case of many of the species soda is extracted from the ash obtained by burning the plants. The Piperacæ contain aromatic and pungent substances; the Urticacæ secrete enzymes in their stinging-hairs (see vol. i. p. 441). The leaves are lobed in Urticacæ and Chenopodiaceæ, in the rest they are undivided and have entire margins. In several Chenopodiaceæ the cauline leaves are squamiform, and assimilation is then effected by the green cortex of the branches, which are transformed into phylloclades. The Piperacæ are distinguished by a peculiar distribution of the bundles in the foliage-leaves. The lateral strands do not branch off from the midrib in the usual way, but are appressed to it and can be traced to the base of the lamina. The Urticacæ also, particularly the genus *Parietaria*, exhibit a peculiar disposition of the bundles (see vol. i. p. 629). The Chenopodiaceæ are destitute of stipules, the Paronychiaceæ have large membranous stipules which protect the foliage-leaves, the Polygonaceæ are distinguished by curious sheathing stipules. In the Caryophyllaceæ and some Paronychiaceæ the floral envelopes are differentiated into calyx and corolla; in Nyctaginaceæ, Amaranthaceæ, and most Polygonaceæ there is a petaloid perianth, whilst in Chenopodiaceæ and Urticacæ there is a sepaloid perianth. The perianth in Nyctaginaceæ resembles a corolla most strongly when the bracts are connate and form a sepaloid envelope or involucre, as is the case, for instance, in the Marvel of Peru (*Mirabilis Jalapa*, see fig. 425). The lowest portion of the perianth in Nyctaginaceæ continues to grow after the flower has faded and forms a leathery or woody investment to the fruit (see fig. 425²). In several Chenopodiaceæ and



Fig. 425. — Nyctaginaceæ, *Mirabilis Jalapa*.

¹ Flowering branch. ² Fruit enclosed in the persistent base of the perianth. ³ Longitudinal section through the same; the true fruit is seen within. (After Baillon.)

Urticaceæ also the perianth persists as a similar investment (e.g. *Morus*). In Amaranthaceæ the pedicels are furnished with bracts which resemble the perianth-segments and, like them, envelop the fruit. In those Centrospermæ which are destitute of floral-leaves (*achlamydeous*), e.g. the Piperaceæ, the floral envelopes are replaced by bracts. The Caryophyllaceæ have distinct calyx and corolla, and are often placed in the sub-class Polypetalæ; they have, however, decided affinities with the Centrospermæ. The andrœcium is composed of one whorl in Urticaceæ and Chenopodiaceæ, and of two whorls in most of the other families. The filaments are inflexed in the bud in Urticaceæ, but spring up when the perianth opens and so eject the pollen from the anthers (see p. 306). Most of the Centrospermæ have dust-like pollen, but in Caryophyllaceæ and Nyctaginaceæ the pollen is adhesive. In Urticaceæ and in some Caryophyllaceæ the embryo is erect, in the rest it is horse-shoe shaped or spirally curved (see fig. 425³). The copious farinaceous endosperm of some Polygonaceæ and Chenopodiaceæ (*Polygonum Fagopyrum*, *P. Tataricum*, *Chenopodium Quinoa*) is used for flour. The Centrospermæ are distributed in every quarter of the globe. The Piperaceæ, Urticaceæ, Polygonaceæ, Amaranthaceæ, and Nyctaginaceæ are developed in the greatest variety in the tropics. Most Centrospermæ, however, are found in the temperate zones. The Mediterranean Flora is especially rich in Caryophyllaceæ, whilst Equatorial America abounds particularly in Amaranthaceæ and Nyctaginaceæ. The Polygonaceæ grow chiefly on the banks of streams; the Chenopodiaceæ are very prevalent by the sea-shore and on salt steppes, especially in Central Asia. Several Caryophyllaceæ flourish also on the confines of perpetual snow. *Silene acaulis* (see Plate XII.) is one of the most remote outposts of the Phanerogamia and has been met with in Franz Joseph's Land at 81° north latitude, and in the Central Alps at a height of 3160 metres above the sea-level. Fossil remains of Urticaceæ and Piperaceæ have been recognized in the deposits of the Mesozoic and Tertiary periods. The number of species now living amounts to about 4200.

Alliance XXXVI.—Proteales.

Family: *Proteaceæ*.

Perennial herbs, with underground stems which project but little above the earth, or herbs and small trees with entire or variously lobed and incised stiff foliage-leaves without stipules. Flowers in capitula or spikes (see fig. 426¹); actinomorphic or zygomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious and dioecious. Perianth 4-partite, petaloid; the four segments are connate at the base, and, in the bud, have their free ends closed together like valves (see fig. 426²). Ovary superior, free, unilocular. Number of ovules one to many. Placentation parietal. Each ovule has a double integument; the micropyle is directed towards the base of the ovary. The latter is surrounded by tissues which secrete honey. The number of stamens is equal to that of the perianth segments; the short filament is adnate to the perianth-segment behind it (see fig. 426³). Fruit a drupe, a nut,

a capsule or a follicle (see figs. 426⁴ and 426⁵, and fig. 324, p. 429). The seed contains an embryo furnished with two large, thick, fleshy cotyledons, but no endosperm.

The Proteales are for the most part much-branched shrubs. The arboreal

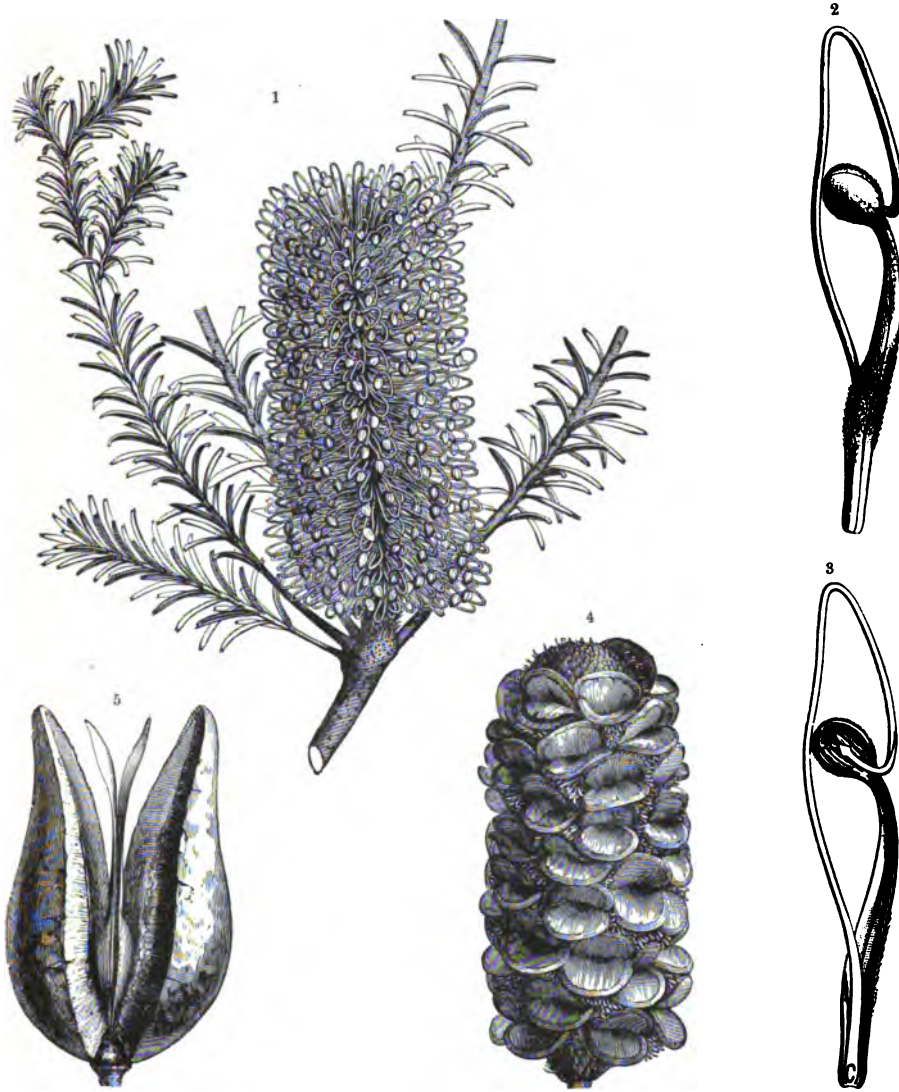


Fig. 426.—Proteales.

¹ *Banksia ericifolia*. ² Single flower of *Banksia littoralis* with the spoon-shaped perianth-segments still closed. ³ Longitudinal section through the same flower; the style is in the form of a barbed hook, and the stigma rests between the anthers; the filaments are adnate to the concave surfaces of the spoon-shaped perianth-segments. ⁴ Fruiting spike of *Banksia ericifolia*. ⁵ Fruit of *Xylomelum pyriforme*. ² and ³ magnified; the rest nat. size. (After Baillon.)

species *Knightia excelsa*, a native of New Zealand, attains a height of 30 metres. The foliage-leaves are sometimes glabrous and sometimes clothed with scales, and they possess peculiar stomata (see vol. i. p. 296). The genus *Hakea* exhibits in

some of its species pinnate and bipinnate leaves, in others cylindrical and needle-shaped leaves. The flowers, which are crowded together, are sometimes surrounded by an involucre of many scales reminding one of the involucre of *Compositæ*. The ovary is often borne on a special stalk. The style and stigma are very various. In many species, as, for instance, in *Banksia ericoides* and *B. littoralis* (fig. 426⁵), the style is hooked and breaks through the perianth-tube in consequence of the excessive longitudinal growth of its lower region, but the capitate extremity remains between the anthers, which are adherent to the spoon-shaped extremities of the perianth. Only when the perianth segments disunite and open back does the top of the style become free. The pollen is often deposited upon the end of the style without, however, immediately reaching the stigmatic surface, and in many species there are special hairs or brushes for collecting the pollen, whilst pockets and recesses for its temporary reception also occur. The *Proteales* flourish chiefly in regions where a short rainy season alternates a long rainless period. Australia and the south-west district of the Cape are richest in species; the alliance is represented by many fewer species in the tropical region of South America, in Chili, in New Caledonia, in New Zealand, in the tropical parts of Eastern Asia, in Madagascar, and in the mountains of tropical Africa. Fossil remains of *Proteaceæ* occur in strata of the Tertiary Period. The number of existing species is about 1000.

Alliance XXXVII.—*Daphnales*.

Families: *Elæagnaceæ*, *Thymelaceæ*, *Lauraceæ*.

Annual and perennial herbs, shrubs, and trees with green foliage, or leafless parasites. Stipules absent. Flowers in fascicles (see fig. 427¹); actinomorphic, hermaphrodite, pseudo-hermaphrodite, or dioecious. Perianth of one or two whorls of 2, 3 or 5 leaves each, sepaloid or petaloid. Gynæceum 1–3 carpellary. Ovary unilocular. Style single, free, at the bottom of a cup-shaped receptacle from the margin of which spring the perianth-leaves (see fig. 427²). Ovule solitary. Androecium 1–4 whorls with 2–4 stamens in each inserted on the inner margin of the cup-shaped receptacle. Fruit a one-seeded berry, drupe, or nut. The seed contains no endosperm. The embryo is furnished with large, fleshy cotyledons.

The *Cassythæ*, belonging to the family *Lauraceæ*, are parasites poorly supplied with chlorophyll, with thin twining stems and squamiform leaves. Most of the *Daphnales*, however, develop woody stems with leafy branches. The leaves of *Elæagnaceæ* are clothed with scaly covering-hairs (see vol. i. p. 322, fig. 78⁵). The foliage-leaves of most *Lauraceæ* exhibit a curious distribution of the strands in the laminæ (see vol. i. p. 631, fig. 149⁴, and accompanying fig. 427¹). The majority of *Lauraceæ* contain ethereal oils and aromatic substances. Especially to be mentioned in this connection are the Bay-Laurel (*Laurus nobilis*), the Cinnamon-tree (*Cinnamomum Zeylanicum*), and the Camphor-tree (*Camphora officinarum*). In the Sea Buckthorn (*Hippophae*, see p. 109, fig. 220), the perianth is 2- and the androecium 4-membered; in *Elæagnus* the perianth and androecium are each composed of two

2-membered whorls; in *Daphne* the perianth has two 2-membered whorls, and the andrœcium two 4-membered whorls (see fig. 427³); in *Laurus* the perianth consists of two and the andrœcium of four 3-membered whorls; in the genus *Gnidium* there are two kinds of floral-leaves, the lower ones sepaloid the upper petaloid in colour, and these are spoken of as calyx and corolla. The same arrangement is found in several *Lauracæ*. The anthers of *Elæagnacæ* and *Thymelacæ* dehisce by longitudinal slits, those of *Lauracæ* by valves (see fig. 427²). In the *Elæagnacæ* the cup-shaped receptacle persists as an envelope around the fruit, and becoming succulent



Fig. 427.—Daphnales.

¹ *Camphora officinarum* (Family Lauracæ), flowering branch. ² Longitudinal section through the flower of *Cinnamomum Zeylanicum* (Family Lauracæ). ³ Flower of *Daphne Mezereum* (Family Thymelacæ) cut open and rolled back
¹ reduced; ² and ³ magnified. (Partly after Baillon.)

outside and strong within, the result is a false drupe. In some of the *Lauracæ* also, as, for instance, in *Nectandra*, the receptacle continues to grow with the fruit, and forms a cup-shaped envelope resembling the so-called cupule in the fruit of the Oak. In *Thymelacæ* and *Lauracæ* the ovule is pendulous (see fig. 427²), in *Elæagnacæ* it is erect. The *Daphnales* are scattered over all parts of the earth. The *Thymelacæ* are best represented in countries where the climate is temperate; the Cape and Australia are particularly rich in species of that family. *Daphne striata* attains its highest elevation in the Central Alps at 2500 metres. There is a striking concentration of several species of the genus *Daphne* on a strictly limited area in the mountainous parts of Southern Europe. One of these species is the plant known in Carniola under the name of the Königsblume (*Daphne Blagayana*).

This name of King's Flower was popularly accorded to the plant because, in 1838, King Augustus of Saxony travelled to Carniola on purpose to see this rare species flowering in its restricted habitat. The Lauraceæ are principally tropical and sub-tropical plants; Eastern Asia, the Sunda Islands, and Brazil are especially rich in species of this family. The Lauraceæ reach their northernmost boundary below 50° in Eastern Asia, below 46° in Europe, and below 45° in North America. In the Southern Hemisphere the Lauraceæ range as far as 43° S. lat. Fossil remains of the Daphnales, especially of Lauraceæ, are found in the strata of the Mesozoic and Tertiary Periods. The number of existing species hitherto discovered is about 1400.

Alliance XXXVIII.—Santalales.

Families: *Santalaceæ*, *Viscaceæ*, *Loranthaceæ*, *Olacaceæ*, *Grubbiaceæ*.

Herbs, shrubs, and trees, of which most are parasitic on the roots and stems of other green-leaved Phanerogams, although they are themselves capable of assimilation owing to the presence of chlorophyll in the foliage-leaves. The leaves have entire margins; there are no stipules. Flowers actinomorphic, solitary or in cymes, which are combined into spikes, racemes, umbels, and capitula; hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious. Perianth composed of 2- or 3-membered whorls; either sepaloid or petaloid. Gynœceum 2-3 carpellary; ovary sunk in the discoid or cup-shaped receptacle, inferior or semi-inferior, unilocular. Style single. Ovules 1-5, without integument. Stamens as many or double as many as the perianth-segments; in the former case they are inserted in front of those segments. Fruit usually a berry or drupe. Seed-coat either single or absent; the embryo either partially or entirely surrounded by fleshy endosperm.

For a description of the sinkers and haustoria of the parasitic Santalaceæ see vol i. p. 177 and pp. 205-213. Several of the Loranthaceæ have thin twining stems which put out roots, *i.e.* sinkers, from their nodes. Such of the Loranthaceæ as are destitute of green foliage-leaves have thickened and flat expanded branches. In certain Santalaceæ several bracts are united so as to form a cup-shaped involucre. In Grubbiaceæ and Olacaceæ the lower portion of the ovary is septate, at least in the first stage of development. In the Santalaceæ and some Olacaceæ 1-5 pendulous ovules are borne upon a cellular structure which is either adnate to the internal wall of the ovary or else rises freely in the cavity; in the Loranthaceæ they completely fill the ovary, and are united with the carpels into a solid mass. In Grubbiaceæ the stamens of the outer whorl alternate with the leaves of the perianth, and there are double as many stamens as perianth-segments. The stamens of the Mistletoe (*Viscum album*, see p. 87, fig. 214²²) are adnate to the perianth-leaves behind them, and their anthers have 6-20 loculi, each of which liberates pollen through a pore. The Santalales are widely distributed. The majority of the species are tropical and sub-tropical. The Olacaceæ only occur in the tropical parts of South America and Africa, and the Grubbiaceæ only at the Cape, whilst the Santalaceæ are chiefly natives of Africa and Australia. The

Mistletoe (*Viscum album*, found in Scandinavia as far north as 59° 30') and several species of the genus *Thesium* reach furthest north. *Thesium alpinum* attains its highest limit in the Alps at 2400 metres. Fossil remains occur in the strata of the Tertiary Period. The number of existing species is about 750.

Alliance XXXIX.—Rafflesiales.

Families: *Rafflesiaceæ*, *Apodanthaceæ*, and *Cytinaceæ*.

Plants destitute of chlorophyll, parasitic on the roots of green-leaved woody plants. Flowering axis greatly thickened, fleshy. Flowers solitary or in racemes, hermaphrodite or pseudo-hermaphrodite. Perianth 4–6 partite. Ovary inferior. The cavity of the ovary is divided irregularly into chambers which are filled with strands and ridges bearing the ovules. Above the ovary rises a columnar style with a discoid thickening at the top, and upon the under margin of this disc the stigmatic tissue is situated. The stamens are inserted underneath the stigmatic tissue in a circle. The fruit is fleshy, baccate, and crowned by the persistent column. The seeds have hard coats. The embryo consists of few cells, has no cotyledons, and is surrounded by an oily endosperm. For a description of the suction-organs see vol. i. pp. 199–204, and for the size of the flowers see vol. ii. p. 185. The Rafflesiales live in the tropical and sub-tropical regions of both the Old and the New World; two species of the genus *Cytinus* (see vol. i. p. 201) belong to the Mediterranean flora. No fossil remains are known. The number of extant species hitherto identified is 29.

Alliance XL.—Asarales.

Families: *Aristolochiaceæ*, *Asaraceæ*.

Perennial plants, some with subterranean tuberous or creeping rhizomes, some with twining liane-like stems (see vol. i. fig. 95¹, p. 364). Foliage-leaves broad, with entire margins, sometimes lobed. Venation apical (see vol. i. p. 633). Flowers hermaphrodite, solitary, or in cymose inflorescences, especially in axillary fascicles. Perianth of 3 petaloid leaves, united at the base. Gynæceum 4–6 carpellary; ovary inferior or semi-inferior. Styles united into a column bearing a radiating stigma. Andræcium composed of 2–12 whorls of 3 stamens each. Ovules numerous in the loculi of the ovary. Fruit a capsule (see p. 431, fig. 325⁶). The seed contains an abundant endosperm, and a very small embryo with two cotyledons.

The perianth in *Asaraceæ* is actinomorphic (see p. 279, fig. 279^{12, 13}), whilst in *Aristolochiaceæ* it is zygomorphic or else unsymmetrical, and the tube of the perianth is variously curved and inflated (see p. 166, fig. 242, and p. 226, fig. 257^{6, 7, 8, 9}). These flowers are very striking, on account not only of their form, but also of their dark-brown colour; moreover, in many cases they attain to an extraordinary size. Mention has already been made of *Aristolochia gigas* (see p. 185), and recently a Birthwort (*Aristolochia Goldeana*) has been found in West Africa which

has a perianth 66 cm. long and 28 cm. broad. In the Asaraceæ there are sometimes three small teeth alternating with the three perianth-segments, and these are looked upon as reduced inner perianth-segments. The stamens of Aristolochiaceæ are adnate to the stylar column (see p. 292, fig. 284¹²). The Aristolochiaceæ are distributed in all parts of the world. The majority of the species are found in tropical and sub-tropical regions. The genus *Asarum* reaches furthest north. The northern limit of the Asarabacca (*Asarum Europæum*) and its highest elevation are the same as those of the Beech. Fossil remains are found in the strata of the Mesozoic and Tertiary Periods. The number of extant species hitherto identified is about 200.

Alliance XII.—Euphorbiales.

Family: *Euphorbiaceæ*.

Annual and perennial herbs, shrubs, and trees. Flowers in racemose or umbellate cymes; actinomorphic, hermaphrodite, pseudo-hermaphrodite, monoecious, and dicecious. Floral-leaves differentiated into calyx and corolla. Calyx and corolla 3-12-merous. The corolla is often suppressed, and sometimes the calyx also is wanting. In these cases the floral-leaves are replaced by bracts and involucre leaves. The gynæceum is superior, and is composed of 3-20 carpels, which are arranged in whorls round a central column. The carpels are joined together to form a multilocular pistil. In the inner angle of each loculus are 1-2 pendulous ovules. The stamens vary in number from 1 to over 100. At the base of the flower are some peculiar glands, which are looked upon as outgrowths of the receptacle. They are either in the form of separate cellular structures, arranged in a whorl, or else are coherent in the form of a cup. In the cases where these structures do not occur they are replaced by similar glands, which are seated upon the margin of the cup-shaped involucre. The fruit is a schizocarp or drupe; sometimes it is baccate. The embryo is imbedded in an abundant fleshy endosperm.

It is difficult to describe the Euphorbiales in few words on account of their extraordinary variety. Some of them contain watery juices; the majority are full of latex. Several of the laticiferous species are poisonous. Many have green foliage-leaves; whilst some are destitute of foliage-leaves, and assimilation is then effected by means of the green cortical tissue of switch-like or cactiform branches and phylloclades. In many genera, especially in *Euphorbia*, the inflorescences have the appearance of being single flowers. A large number of male flowers are assembled together within a cup-like involucre, the free edge of which is furnished with glands as though with petals. Each of these flowers consists, however, merely of a bract and a stamen, and in the midst of them is a female flower, borne at the end of a long stalk, and resembling a stalked ovary. In many species of the genera *Croton* and *Poinsettia* the inconspicuous flowers are surrounded by bright-coloured bracts and involucre leaves. In the majority of instances three carpels are developed, which are remarkable for their rotundity. They are laterally coherent, and usually separate when mature, and become detached from the central column. The

Euphorbiales are distributed in every quarter of the globe. The majority are found in the tropics, and several arboreal species form entire woods in those regions. Some grow in marshy lowlands, whilst others inhabit steppes and the rocky declivities of mountains. *Euphorbia capitulata* grows on the mountains of the Balkan Peninsula. *Euphorbia Austriaca* stretches as far as the alpine region of the Eastern Alps. *Mercurialis perennis* attains in the Alps an elevation corresponding to the upper limit of the Beech-forests. Several annual species of *Euphorbia* are encountered as weeds in cultivated ground, as far as the limits of the arctic region. Fossil remains have not been definitely ascertained to exist. The number of extant species hitherto identified is about 4000.

Alliance XLII.—Podostemales.

Family: *Podostemaceæ*.

Perennial herbs with creeping roots which are fastened to the substratum. The shoots spring laterally from these roots, and are clothed by small scales arranged in two or three rows; these leaves are either entire or pinnately lobed, and they are sheathed at the base. Not infrequently the shoots are transformed into phylloclades, and sometimes shoots and roots are fused together into a thalloid structure. In these cases the assimilation of carbon is effected by the phylloclades as well as by the green branches of the thalloid tissue clinging to the substratum. The branches in question are ribbon-shaped or filiform, and are submerged. The flowers occur singly at the ends of the shoots, or else are sunk in the margins of the phylloclades in rows, and together form a sort of flat club. They are actinomorphic and zygomorphic, hermaphrodite, monœcious, and dioecious. The floral-leaves are small, greenish, squamous, free, or connate, and are arranged in a 3-5-partite whorl. When the floral-leaves are suppressed, they are replaced by sheathing involucreal leaves. The gynæceum is composed of 1-3 carpels; the ovary is superior, and either unilocular or else divided by delicate partition-walls into three chambers. The ovules spring from cushions of tissue which project from an axial column in the ovary. The number of stamens varies greatly, the flowers being either monandrous, diandrous, or polyandrous. In the last case the stamens are arranged in several whorls. The anthers dehisce longitudinally. The fruit is a capsule. The seeds are very small, and do not contain any endosperm. The embryo has two thick cotyledons.

The Podostemaceæ are found in running water, especially in waterfalls, clinging to rocks, loose stones, and stumps of trees which have been stripped of their bark. Almost all of them inhabit the tropics, the only exception being one species in South Africa and one in North America. No fossil remains have been found. The number of existing species hitherto described amounts to 175.

Alliance XLIII.—Viridifloræ.

Families: *Leitneriaceæ*, *Cannabinaceæ*, *Dorsteniaceæ*, *Artocarpaceæ*, *Ficaceæ*, *Conocephalaceæ*, *Moraceæ*, *Ulmaceæ*

Annual or perennial herbs, shrubs, and trees. The laminæ of the foliage-leaves veined with pinnate or radiating bundles. Flowers in glomerate, fasciculate, or spicate cymes; actinomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious, and dioecious. Perianth composed of 2–8 inconspicuous greenish segments. Gynæceum superior, 1–2 carpellary and unilocular. Ovule solitary, pendulous. Stamens as many or double as many as the perianth-segments; all or those of the outer whorl are



Fig. 428.—“Living bridge” formed of the aerial roots of the India-rubber and other kinds of Figs in Sikkim-Himalaya. (After Hooker.)

inserted opposite the segments of the perianth. The pollen is dusty. The fruit is a one-seeded achene or a drupe. The cotyledons of the embryo are not thickened.

The *Ulmaceæ* and *Cannabinaceæ* contain watery juices; the plants of the other families produce milky juice in greater or smaller quantity. The milky juice of the Indian *Ficus elastica* is used in the manufacture of caoutchouc, that of the South American Cow-tree (*Galactodendron utile*) as an article of diet. The milky juice of the Upas-tree (*Antiaris toxicaria*), native to Java, contains poisonous substances. In the Hop (*Humulus Lupulus*) and in the Hemp (*Cannabis sativa*) bitter and



Fig. 429.—Amentales.

¹ Birch (*Betula alba*) shoot with male and female catkins (the former at the apex). ² Ripe female catkin of same. ³ Winged nut of same. ⁴ Subtending scale of fruit of same. ⁵ Shoot of Hornbeam (*Carpinus Betulus*) with male and female catkins (latter to right). ⁶ Scale of female catkin with flowers of same. ⁷ Scale from male catkin with stamens. ⁸ Scale of female catkin with ripe fruit. ³, ⁴, ⁶, ⁷ enlarged; the rest nat. size.

aromatic substances (lupulin and hashish) are produced in special cells and groups of cells. The curious tabular and columnar roots of the Ficaceæ have been described in detail and illustrated in vol. i. pp. 755-757. Here is represented a *Ficus* (fig. 428) with aerial roots, which Hooker saw used by the natives in the Himalaya as bridges. "The property of the fig-roots, which inosculate and form natural grafts, is taken advantage of in bridging streams, and in constructing what are called 'living bridges' of the most picturesque forms." The axis of the inflorescence is thickened in many cases, notably in the Dorsteniaceæ, Artocarpaceæ, Ficaceæ, Conocephalaceæ, and

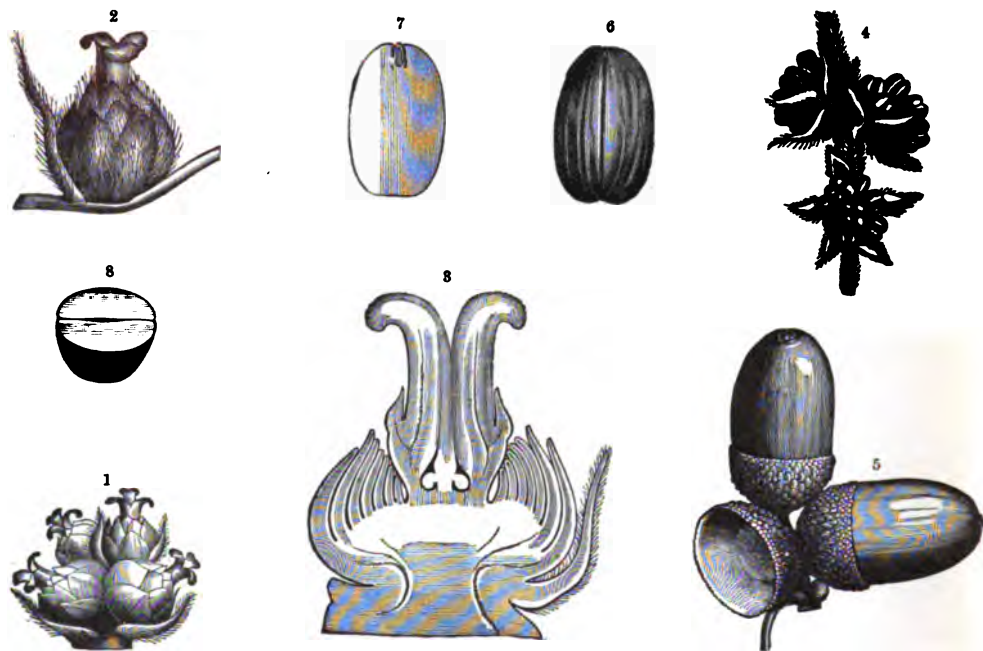


Fig. 480.—The Oak (*Quercus sessiliflora*).

¹ Cluster of female flowers. ² Single female flower. ³ Longitudinal section of a female flower showing the ovary with ovules, small perianth and the young cup or cupule. ⁴ Three male flowers. ⁵ Cluster of nuts (acorns) with their cupules. ⁶ The seed. ⁷ Longitudinal section of seed. ⁸ Transverse section of seed. ¹, ², ³, ⁴ enlarged; rest nat. size.

Moraceæ; sometimes it is discoid, and sometimes hollowed out into the shape of an urn (see p. 157). It also enters into the structure of certain fleshy succulent collective fruits, which afford such an important article of food in hot countries, viz. the figs of *Ficus*, and the Bread-fruit of *Artocarpus incisa*. Sometimes the perianth also takes part in the formation of the fruit, as, for instance, in the Mulberry (*Morus*), where it is converted into a fleshy envelope inclosing the fruit. On the other hand, in several other Viridifloræ the perianth is almost completely suppressed. In Dorsteniaceæ and Moraceæ the stamen-filaments are inflexed in the bud, and spring up after the perianth has opened, scattering the pollen-dust in the air (see fig. 229, p. 137). The filaments are straight in the flowers of the other families. The embryo is curved in most cases. There is either a very small quantity of endosperm or none at all. The Viridifloræ are found in all parts of the world. The Ulmaceæ extend



Fig. 431.—The Beech (*Fagus sylvatica*).

beyond 66° north latitude and 36° south latitude. Representatives of Viridifloræ are most abundant in the tropics. Fossil remains occur in the deposits of the Mesozoic and Tertiary Periods. The presence of leaves of a Bread-fruit tree (*Artocarpus Dicksoni*) in Greenland chalk, and of quantities of remains of Ulmaceæ (*Celtis*, *Zelkova*, *Ulmus*) in the Miocene strata, are points of special interest. The number of species ascertained to exist at the present day is about 1000.

Alliance XLIV.—Amentales.

Families: *Betulaceæ*, *Corylaceæ*, *Cupuliferæ*, *Juglandaceæ*, *Myricaceæ*, *Casuarineæ*, *Salicaceæ*.

Are all large shrubs and forest trees, forming a very conspicuous feature in the landscape in temperate climates. The flowers are unisexual and arranged in catkins or heads. Pollination is by wind, and, in the majority of cases, a perianth is wanting. In the Cupuliferæ, in which it is present, it is inconspicuous and consolidated with the ovary. The group is an exceedingly interesting one, owing to the recent discovery of several instances of chalazogamic fertilization within its limits; of this, full details were given at p. 413. In this alliance are included such familiar trees as the Birch (*Betula*, figs. 429^{1,2,3,4}), Alder (*Alnus*, p. 135), Hazel (*Corylus*, p. 147), Hornbeam (*Carpinus*, p. 433 and figs. 429^{5,6,7,8}), Oak (*Quercus*, p. 298 and fig. 430), Beech (*Fagus*, fig. 431), Chestnut (*Castanea*, p. 445), Walnut (*Juglans*), Sweet-gale (*Myrica*), *Casuarina*, and the Willow (*Salix*, pp. 299 and 424) and Poplar (*Populus*). Between 500 and 600 species have been distinguished. Members of this alliance date far back amongst the secondary rocks, and they are supposed by many to represent a primitive group of Angiosperms.

Alliance XLV.—Balanophorales.

Families: *Hydnoraceæ*, *Sarcophytaceæ*, *Cynomoriaceæ*, *Balanophoraceæ*, *Scybaliaceæ*.

Plants destitute of chlorophyll, parasitic on the roots of green-leaved woody plants, with tuberous, cylindrical, or angular stems with flowering lateral branches. The flowering axes are thickened and fleshy; the flowers hermaphrodite or pseudo-hermaphrodite, monœcious or dicecious. Perianth of 2–8 segments, sometimes transformed into a cup on the top of the ovary, or absent and replaced by scaly bracteoles and hairs. Gynæceum 1–3 carpellary; ovary inferior, unilocular, styles either absent or 1–2 in number, filiform, and terminating in small stigmas. Stamens 1–60 inserted below the limb of the perianth. Fruit a kind of berry, nut, or drupe. The embryo is very small, has no cotyledons, and is imbedded at the top of a fleshy, oily endosperm.

For a description of the suckers and scale-leaves, see vol. i. pp. 186–198. The flowers of Hydnoraceæ are solitary; those of Balanophoraceæ, Cynomoriaceæ, and Scybaliaceæ are crowded in large numbers on unbranched clavately-thickened axes,

and those of Sarcophytaceæ on branched clavate axes. In Hydnoraceæ the cavity of the ovary is occupied by numerous ridges which project from the walls and bear the ovules; in Sarcophytaceæ, Scybaliaceæ, Cynomoriaceæ, and Balanophoraceæ the placentation is parietal, and the number of the seeds is 3 in Sarcophytaceæ, 2 in Scybaliaceæ, 1-3 in Cynomoriaceæ, and 1 in Balanophoraceæ. In Hydnoraceæ and Sarcophytaceæ there is no style, and the free upper extremities of the masses of tissue which bear the ovules act as stigmas. The Cynomoriaceæ and Balanophoraceæ have one, and the Scybaliaceæ two, filiform styles with small papillose stigmas. In Hydnoraceæ the stamens are inserted between the lobes of the perianth, and form a fleshy ring; in the other families they stand in front of the segments of the perianth; in the Balanophoraceæ the filaments are connate. Most of the Balanophoraceæ live in the tropical parts of Asia and America; a few species inhabit South Africa and New Holland. *Cynomorium coccineum*, the only species of the Cynomoriaceæ, grows in the Mediterranean area and in Western Asia (see vol. i. p. 197, fig. 42). Fossil remains are not known. The number of extant species hitherto discovered is about 45.

Sub-Class II.—MONOPETALÆ.

Alliance XLVI.—Caprifoliales.

Families: *Rubiaceæ*, *Caprifoliaceæ*

Annual and perennial herbs, shrubs, and trees. The foliage-leaves are opposite, stipules are present at their bases (see fig. 432¹). The flowers are in cymes, actinomorphic and zygomorphic, hermaphrodite and pseudo-hermaphrodite. The floral-leaves are differentiated into calyx and corolla. The calyx is composed of one 2-6-sepalous whorl. The calyx-tube clothes the inferior ovary, whilst the limb consists of small green teeth. The corolla is a whorl of 3-6 connate petals (see fig. 432³). The gynæceum is composed of 2-5 connate carpels; ovary inferior, 2-5 locular. The placentas are axile. The androecium is a whorl of 3-6 stamens, adnate to the corolla-tube. The pollen is either adhesive or powdery (see p. 265). The fruit is a berry, drupe, schizocarp, or capsule. The seed contains endosperm.

Most of the Rubiaceæ are herbaceous, whilst the species of the other families are mostly shrubby and arboreal plants. In the roots of several Rubiaceæ (e.g. *Rubia tinctorum* and *Galium boreale*) there is a red colouring matter (madder-red); the Coffeaceæ and Cinchonaceæ contain alkaloids (caffeine, quinine, &c.); the sweet-scented Woodruff (*Asperula odorata*), the herb used to make the German May-wine, is famous for the kumarin it contains. No laticiferous tubes or latex, however, are contained in the tissues of any species belonging to this alliance. The foliage-leaves are always opposite and in pairs, which are at right angles to one another; the venation of the laminæ is pinnate. In the Stellatæ section of Rubiaceæ the stipules are of the same size, colour, and form as the laminæ of the opposite leaves to which they belong, and are inserted between them. The consequence is that at each node there is a whorl of leaf-structures arranged in the form

of a star. In the *Cinchonaceæ* and *Coffeaceæ*, the stipules are squamiform, and sometimes lacerated (see fig. 432¹). In the *Caprifoliaceæ* they are either very small and in the form of stalked glands, or else they are adnate to the base of the petiole, and have the appearance of being narrow sessile segments of the leaf. The cymose inflorescences may be contracted into glomerules and fascicles, in which case each is surrounded by an envelope of bracts, as, for instance, in the *Ipecacuanha* plant (*Cephaelis Ipecacuanha*; see fig. 432²), or they may form pyramidal panicles, as in the *Cinchona*, or, lastly, they may be flat cymes, as in the Elders (*Sambucus nigra*

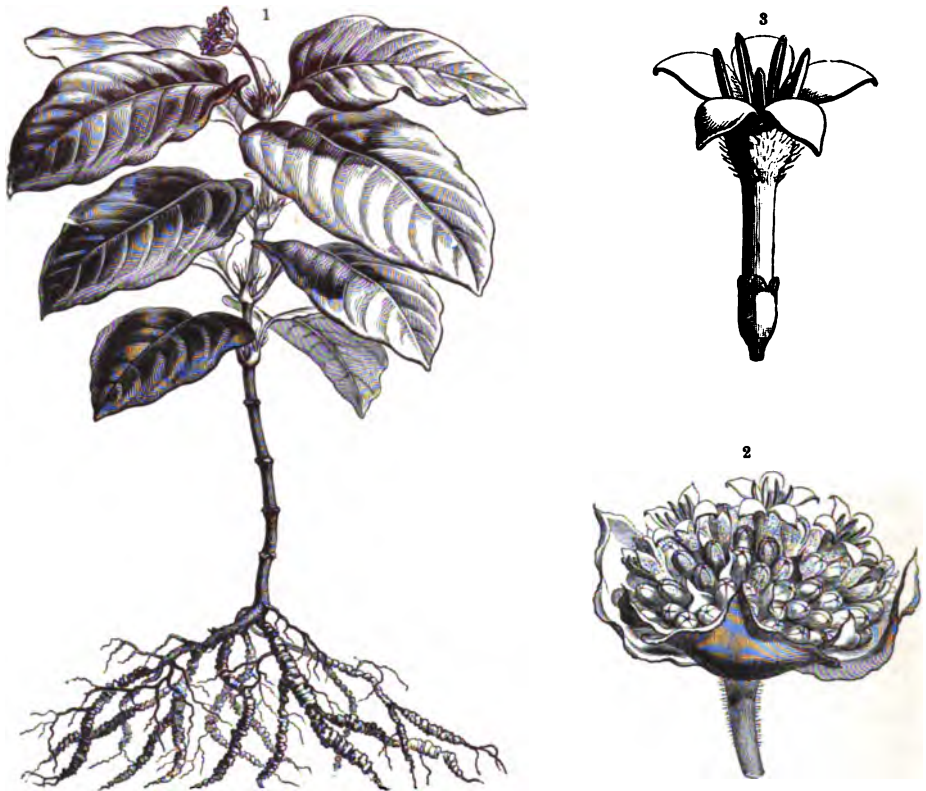


Fig. 432.—Caprifoliales: *Cephaelis Ipecacuanha* (Family Rubiaceæ).

¹ Entire Plant. ² Inflorescence. ³ Single flower. ¹ reduced; ² and ³ magnified. (After Baillon.)

and *S. Ebulus*). In the *Caprifoliaceæ*, especially in the genera *Linnæa* and *Lonicera*, two-flowered cymes also occur, and in several species of the genus *Lonicera*, the ovaries of the two flowers in each cyme are connate. The flowers of several *Caprifoliaceæ* (*Linnæa*, *Lonicera*, &c.) are zygomorphic, whereas the other members have actinomorphic flowers. In the *Stellatæ* the fruit is a schizocarp which breaks up into two mericarps; in *Cinchonaceæ*, it is a capsule which dehisces from the base upwards (see p. 431, fig. 325¹⁰). In *Coffeaceæ*, *Sambucaceæ*, and the genus *Linnæa*, the fruit is a drupe, and in *Gardeniæ* and some of the *Caprifoliaceæ*, a berry. The baccate fruits of several species of the genus *Lonicera* (*L. alpigena* *L. cærulea*, &c.), coalesce to form a collective fruit. Each chamber in the fruit of

Rubiaceæ, Coffeaceæ, Sambucaceæ, and of the genus *Linnaea*, contains one seed, in most Caprifoliaceæ, as in the genus *Lonicera*, several, and in the Cinchonaceæ, many seeds. The seeds of Cinchonaceæ are winged (see p. 423, fig. 318⁷).

The Caprifoliales are distributed over all parts of the earth. The Coffeaceæ and Cinchonaceæ are chiefly tropical plants, whilst the Rubiaceæ, Sambucaceæ, and Caprifoliaceæ belong principally to the North Temperate Zone. The *Cinchona* is found wild only in the Cordilleras in South America (from 10° north lat. to 22° south lat.). Tropical Africa is supposed to be the original home of the Coffee-tree (*Coffea Arabica*). *Linnaea borealis*, a plant named after the Swedish botanist, Linnæus, is scattered over the Alps, in the low-lying part of Germany adjoining the Baltic, and in Scandinavia. Several species of the genus *Galium*, of the family Rubiaceæ, belong to the flora of the extreme North and of high mountains. Fossil remains have been preserved in the deposits of the Mesozoic and Tertiary Periods. The number of extant species discovered up to the present time is about 4800.

Alliance XLVII.—Asterales.

Families: *Valerianaceæ*, *Dipsaceæ*, *Calyceraceæ*, *Brunoniaceæ*, *Compositæ*.

Annual and perennial herbs, shrubs, and trees. Foliage-leaves extremely various in form but always destitute of stipules. Inflorescence a cyme or a capitulum. Flowers actinomorphic and zygomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious. Floral-leaves differentiated into calyx and corolla. Calyx of 2–5 sepals; the limb, which crowns the inferior ovary, is in the form of a pappus, bristles, scales, teeth, callosities, or membranous borders, and is destitute of chlorophyll. The corolla is composed of 4–5 connate petals. The gynæceum consists of 2–3 connate carpels. The ovary is inferior and contains only one developed loculus with a single ovule in it (see p. 73, fig. 207⁵). The androecium consists of 1–5 stamens. The filiform filaments are adnate at the base to the corolla-tube. The fruit is a unilocular, one-seeded achene.

The plants belonging to this alliance exhibit for the most part herbaceous growth, but some *Compositæ* are shrubby (e.g. *Baccharis*), and some arboreal (e.g. *Vanillosmopsis*, *Lychnophora*). Several *Valerianaceæ* and *Compositæ*, e.g. the *Dahlia* and Jerusalem Artichoke (*Dahlia variabilis* and *Helianthus tuberosus*), are distinguished by underground tuberous structures. The inflorescence in *Valerianaceæ* is a much-branched cyme (see p. 305, fig. 289¹). In *Dipsaceæ* also the arrangement of the flowers is cymose, but the cymes are usually grouped together in capitula (see p. 121, fig. 225⁵). In some genera, such as *Morina*, they are arranged in opposite fascicles in the same manner as in *Labiata*. The flowers of *Compositæ* are situated at the extremity of a thickened axis which is conical, hemispherical, or flat, and compressed, as the case may be; they are spirally arranged and are grouped together in capitula (see p. 242). In many cases they spring from the axils of scales ("paleæ"), or else their place of origin is surrounded by bristles. Not infrequently they spring from little depressions, and then the axis is seen to be pitted when the

flowers have fallen off. The number of flowers in a capitulum varies greatly. In many species several hundreds of flowers (florets) are crowded together, in *Adenostyles* and *Eupatorium* (see p. 320, fig. 294¹) there are only a few flowers in each capitulum, and in *Echinops* it is limited to a single one. The capitulum is surrounded by an involucre of bracts crowded together. The form of these involucreal leaves exhibits extreme variety. In Thistles their apices are transformed into prickles, in the species of the genus *Xeranthemum*, *Helichrysum*, &c., they are like paper or parchment, dry, and distinguished by white, yellow, violet, and red colours. They preserve these characteristics unchanged even when dried, and can therefore be made up into bouquets and wreaths which do not fade. These composite flowers, which are known as "immortelles", are everywhere used as symbols of immortality and as memorial tokens. The Cape is exceptionally rich in Everlasting Flowers; among the species found there is *Helichrysum eximium*. The Edelweiss (*Gnaphalium Leontopodium*, see vol. i. p. 315, fig. 76) may also be looked upon as an immortelle, although here the bracts are not themselves dry and membranous, but are only covered with a dry, white felt of hairs. In many species the capitula are themselves grouped in capitula or glomerules. One of the most striking instances of this is afforded by the species of the genus *Haastia*, which are shown on p. 188. In the genus *Echinops* a large number of one-flowered capitula are grouped together in spherical heads, usually of a steel-blue colour. The capitula often look like single flowers, and in former times they were looked upon by botanists as compound flowers (*flores compositæ*), whence the name of Compositæ. In many species, e.g. the Sun-flower (*Helianthus annuus*), the capitula attain to a diameter of 40 centimetres. In the actinomorphic corollas a tube and a bell-shaped 5-partite limb may be distinguished (see p. 360, figs. 302^{1, 2, 3}). The zygomorphic flowers are either two-lipped, the upper lip being composed of one or two petals, and the under lip of four or three petals, or else ligulate, in which case the tube is greatly abbreviated and the free end of the ligule usually exhibits five segments or teeth (see p. 121, fig. 222⁴, and p. 236, fig. 261⁵). In Valerianaceæ the corolla is usually produced on one side into a kind of sac, which in the genus *Valeriana* is short and blunt (see p. 289, fig. 283⁶), and in the genus *Centranthus* is in the form of a long, slender, pointed spur (see p. 240, fig. 263², and p. 305, figs. 289^{2, 3}). In the capitula of Compositæ the flowers with tubular, ligulate, and bilabiate corollas respectively are grouped together in a great variety of ways. It is not common for all the flowers of a capitulum to have tubular flowers, but that is sometimes the case (e.g. *Eupatorium*, p. 320, fig. 294¹); much more frequently all the flowers in a capitulum have ligulate corollas (e.g. *Hieracium*, p. 112, fig. 222⁵), and in the majority of instances the flowers in the middle of the capitulum are furnished with tubular corollas, and those near the periphery with ligulate or bilabiate corollas (see p. 360, fig. 302¹). The distribution of the sexes has been dealt with on pp. 295–297, and pp. 318–321. In the Compositæ the anthers of the five stamens are united into a tube. The anthers are not connate in the other families. In Dipsacæ the androecium consists usually of four stamens, and in Valerianaceæ usually of three stamens (see p. 289,

fig. 283³); the genera *Morina* and *Fedia* have two stamens in each flower, whilst the genus *Centranthus* (Red Valerian) has only one (see p. 240, fig. 263²). For a description of the pollen of Compositæ see p. 99. The gynæceum in Valerianacæ is composed of three carpels, and the ovary is originally 3-locular, but two of the carpels are abortive, and only the third loculus is completely developed. In the other families the ovary is unilocular from the first. The ovule and the seed resulting from its development is pendulous (see p. 178, fig. 249, and p. 240, fig. 263²) in Dipsacæ and Valerianacæ, basal (see p. 73, fig. 207⁵) in Compositæ. In most cases the calyx remains adnate to the mature fruit and assumes the form of a crown of hairs or bristles, which is termed a "pappus" (see p. 432), or else constitutes a membranous limb. In a later chapter we shall deal with the significance of these structures. In the Dipsacæ the fruit is surrounded by a saccate involucre called an involucre. The alliance is distributed over all parts of the earth; its members flourish both in the tropics and in the arctic regions, and are met with on the sea-shore and by the side of glaciers, in bogs and on arid ground, in shady woods and on sandy steppes. The greatest number are natives of the North Temperate Zone. In the Himalayas several Composites occur at an elevation of 4500 metres. Fossil remains have been found in small quantities in the deposits of the Mesozoic and Tertiary Periods. The number of extant species identified up to the present time is about 10,700.

Alliance XLVIII.—Campanales.

Families: *Campanulacæ*, *Lobeliacæ*, *Stylidiacæ*, *Goodeniaceæ*.

Annual and perennial herbs with entire exstipulate foliage-leaves arranged spirally. Flowers in capitula or racemes, or else solitary; actinomorphic or zygomorphic, hermaphrodite or pseudo-hermaphrodite. Floral-leaves differentiated into calyx and corolla. Calyx of one whorl of 3–8 sepals, corolla of one whorl of 3–8 petals. The calyx-tube clothes the inferior ovary, and the calyx-limb is in the form of 3–8 comparatively large, green segments which crown the top of the ovary. The petals are joined. The gynæceum is composed of 2–5 connate carpels; the ovary is inferior and 2–5 locular. The ovules are numerous, and are borne on axile placentas. The andræcium consists of one whorl of 3–8 stamens, which are attached to the bases of the petals. The filaments are free; in the young flower the anthers are in close contact, forming a tube surrounding the style (see p. 360, figs. 302^{10, 11}). Sometimes they are connate, and in that case the tube persists even when the flower begins to fade. The pollen is adhesive. The fruit is a capsule (see fig. 340¹, p. 448).

All the Campanales have laticiferous tubes running through them, and in several species the leaves and stems are copiously supplied with latex. The flowers are actinomorphic in Campanulacæ, zygomorphic in the other families. In the Stylidiacæ, only two of the stamens develop pollen capable of effecting fertilization, whilst three stamens are abortive; in the other families all the stamens produce

pollen, which ripens effectually. The Campanales are distributed over all quarters of the globe. The Campanulaceæ are mostly natives of the North Temperate Zone, the Lobeliaceæ of the South Temperate Zone and the Tropics. Some Campanulaceæ are also found amongst the flora of the Arctic regions, and of high mountains. The Stylidiaceæ and Goodeniaceæ are confined to Australia. No fossil remains have been discovered. The number of identified species now living is about 1300.

Alliance XLIX.—Ericales.

Families: *Diapensiaceæ*, *Pyrolaceæ*, *Monotropaceæ*, *Lennoaceæ*, *Arbutaceæ*, *Rhodoraceæ*, *Ericaceæ*, *Epacridaceæ*, *Empetraceæ*, *Ebenaceæ*, *Sapotaceæ*.

Perennial herbs, shrubs, and trees. Flowers actinomorphic and zygomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious, and dioecious. The floral-leaves arranged in two 3-5 partite whorls. The lower whorl constitutes a calyx, the upper a corolla. The petals are free in *Pyrolaceæ* and *Monotropaceæ*; in the other families they are coherent, at any rate at the base. The gynæceum is composed of 3-10 carpels; the ovary is superior, and 3-10 celled. The ovules arise from an axile placenta. The andrœcium is composed of one or more whorls of 4-5 stamens each. In many cases some of the stamens are metamorphosed into gland-like structures. The fruit is a capsule, berry or drupe. The embryo is erect, and imbedded in the fleshy endosperm.

The *Diapensiaceæ* and *Pyrolaceæ* (see figs. 277^{7,8}, p. 273), are perennial herbaceous, or suffruticose plants, which grow in black humus, and have stiff, evergreen foliage-leaves; the *Monotropaceæ* and *Lennoaceæ* are parasites or saprophytes (see vol. i. p. 252), and are destitute of chlorophyll. The *Arbutaceæ*, *Rhodoraceæ*, *Ericaceæ*, *Epacridaceæ*, and *Empetraceæ* are, for the most part, dwarf shrubs; only a few are trees. *Erica arborea*, one of the Mediterranean Flora, when able to grow without hindrance, attains the height of 8 metres. The branches of *Ericaceæ*, *Epacridaceæ*, *Empetraceæ*, and of *Loiseleuria* or *Azalea procumbens*, one of the *Rhodoraceæ*, are thickly covered with stiff, rolled leaves (see vol. i. p. 303²). The species of the genus *Rhododendron* have flat foliage-leaves (see Plate X.), as have also the *Arbutaceæ* (see fig. 433¹). The leaves of *Arctostaphylos alpina*, *Azalea Pontica*, and *A. mollis* are green in the summer only, whilst most of the *Arbutaceæ* and *Rhodoraceæ* have flat, evergreen foliage. The *Ebenaceæ* and *Sapotaceæ* exhibit, in a large proportion of their species, arboreal growth and leathery foliage-leaves. All the *Ericales* are distinguished for their solid timber. Some of the *Rhodoraceæ* have zygomorphic flowers; the rest of the *Ericales* have actinomorphic flowers. In *Loiseleuria*, and in the *Empetraceæ* and *Epacridaceæ*, the androecium is composed of one whorl; in the others it consists of two or more whorls. The anthers of *Arbutaceæ* and of many *Ericaceæ* possess two peculiar horn-like appendages (see figs. 433³ and 433⁴, and figs. 216^{9,10,11}, p. 91). In *Epacridaceæ* the anthers are unilocular, and dehisce longitudinally; in *Ericaceæ*, *Arbutaceæ*, *Rhodoraceæ*, and *Pyrolaceæ* they usually open by terminal chinks or pores (see p. 91, figs. 216^{8,9,10,11,12}).

The pollen is dusty in Ericaceæ, but adhesive in most other cases. The pollen-cells are united in fours in Ericaceæ, Rhodoraceæ, and Pyrolaceæ, and in the Rhodoraceæ these groups are connected by tough threads (see figs. 219^{2, 3, 4}, p. 101). The fruit is capsular in Diapensiaceæ, Pyrolaceæ, Monotropaceæ, Rhodoraceæ, Ericaceæ, and Epacridaceæ, and baccate in Arbutaceæ, Empetraceæ, Sapotaceæ, and Ebenaceæ. In the Lennoaceæ the fruit resolves itself into 10–28 one-seeded portions. The Ericales are distributed over the whole world; the Ebenaceæ and Sapotaceæ live chiefly in the tropics; the Lennoaceæ are confined to the southern half of North America, and the Epacridaceæ to Australia. The species of Ericaceæ are most abundant at the Cape. Most of the species of the genus *Rhododendron* inhabit



Fig. 488.—Ericales: *Arbutus Unedo* of the family Arbutaceæ.

¹ Flowering branch. ² Three flowers magnified. ³ Longitudinal section through a flower. ⁴ Flower from which the corolla has been removed. ⁵ Papillose berry. ², ³ and ⁴ magnified. (After Baillon.)

the mountains of Central Asia, *e.g.* the Himalayas. The genus *Kalmia* belongs to the mountains of North America. The Diapensiaceæ live in the arctic regions, as also do several Ericaceæ. *Loiseleuria* or *Azalea procumbens* is widely distributed in the arctic regions, and also occurs in exactly the same form on the mountains of Central and Southern Europe; in the Central Alps it attains its maximum elevation of 2700 metres above the sea-level. Most of the Ericales grow sociably on rocky declivities in mountainous districts, and on sandy soil in plains. Many only flourish on moorland, or when rooted in a deep layer of humus, and these play an important part in the formation of peat. Fossil remains are found in the deposits of the Mesozoic, Tertiary, and Diluvial periods. The number of extant species known is about 2300.

Alliance L.—Vacciniales.

Families: *Vacciniaceæ*, *Oxycoccaceæ*.

Woody plants, presenting all gradations in form, from that of delicate dwarf shrubs lying upon the ground to that of stately trees. The foliage-leaves arranged spirally, exstipulate. Flowers in racemes and fascicles, or solitary; actinomorphic, hermaphrodite. Floral-leaves differentiated into calyx and corolla. The calyx is composed of a whorl of 4–6 sepals. The calyx-tube clothes the inferior ovary; the calyx-limb is in the form of short, green teeth, crowning the top of the ovary. The corolla consists of a whorl of 4–6 petals; the petals are united or free. The gynæceum is composed of 4–6 connate carpels. The ovary is inferior and 4–6-locular. The placentas are axile. A honey-secreting tissue is situated on the top of the ovary. The andrœcium consists of two whorls with 4–6 stamens in each. The stamens surround the nectary, and are free from one another and from the corolla. The members of the outer whorl are opposite the petals. The fruit is a berry or a drupe. The seed contains a fleshy endosperm.

The Vacciniales have no laticiferous tubes or latex. In *Vacciniaceæ* the petals are united, and the anthers are furnished with horn-shaped appendages, in *Oxycoccaceæ* the petals are free, and the anthers have no horns. The Vacciniales are distributed in all quarters of the globe, and in all latitudes. The species which belong to the Temperate Zones grow in peat-bogs and in the humus of woods and heaths, the species native to the mountains of tropical regions are, in some cases, epiphytic on the bark of old trees. Many are of social habit, and cover extensive tracts of ground. This is the case, for instance, with the various species of the genus *Vaccinium*: the Cow-berry (*Vaccinium Vitis-Idæa*), the Bilberry (*Vaccinium Myrtillus*), and *Vaccinium uliginosum*. These species are also found within the area of the Arctic Flora. *Vaccinium uliginosum* ranges furthest to the North, and in Greenland forms with the dwarf Birch (*Betula nana*) and dwarf Willows, a low undergrowth which reaches to 73° N. Lat. They clothe the mountain sides in the Central Alps as far as 2400 metres above the sea-level. Fossil remains have been found in the deposits of the Mesozoic, Tertiary, and Diluvial Periods. The number of extant species hitherto recognized amounts to about 350.

Alliance LI.—Primulales.

Families: *Primulaceæ*, *Plumbaginaceæ*, *Myrsinaceæ*.

Annual and perennial herbs, shrubs, and small trees with alternate, opposite, and verticillate foliage-leaves. Flowers solitary, or in spikes and racemes; actinomorphic, hermaphrodite or pseudo-hermaphrodite. The floral-leaves are arranged in two whorls of 4–8 segments each. The lower whorl constitutes a calyx, the upper a corolla. The petals are coherent. The pistil is superior, 5-carpellary, unilocular. The ovules are supported in the middle of the ovary on a column of varying length

rising from the bottom of the ovary. The stamens, five in number, are inserted in front of the petals, and are adnate to them (*epipetalous*). The fruit is a unilocular capsule or drupe. The seeds contain an endosperm, in which the embryo is embedded.

The ovary is surmounted by a single style in Primulacæ and Myrsinacæ, by five styles in Plumbaginacæ. The capsules of Primulacæ are many-seeded, those of Plumbaginacæ are one-seeded. In the genus *Glaux* only one floral envelope is developed. It has the appearance of a perianth, and resembles that of Polygonacæ. It is interpreted as being a petaloid calyx. The fact that in *Glaux* the stamens occupy the same position in relation to the sepals as the petals do in other cases warrants our supposing that what is usually designated as the corolla in Primulacæ is only a whorl of stamens with connate petaloid filaments. The Primulacæ are distributed mainly in the temperate zone of the Northern Hemisphere. Most of the species of the genera *Primula*, *Soldanella*, and *Androsace* are alpine plants. The Alps and the Himalayas are particularly rich in these species. *Androsace glacialis* (see fig. 221⁶) occurs in the Alps in the neighbourhood of glaciers at a height of 3160 metres above the sea-level. *Primula pubescens*, a plant obtained by Clusius in 1582 from the Gschnitzthal in Tyrol, was the original species from which Auriculas were derived during the fashion for their cultivation which prevailed in the seventeenth century. The Plumbaginacæ are represented by large numbers of species on the shores of the Mediterranean and in the saline steppes of the East. The Myrsinacæ grow exclusively in the tropics. Fossil remains of Myrsinacæ are known amongst the deposits of the Tertiary period. The number of species now existing is about 1100.

Alliance LII.—Tubifloræ.

Families: *Gentianaceæ*, *Asclepiadaceæ*, *Apocynaceæ*, *Loganiaceæ*, *Convolvulaceæ*, *Polemoniaceæ*, *Hydrophyllaceæ*, *Boraginaceæ*, *Nolanaceæ*, *Solanaceæ*, *Scrophulariaceæ*, *Lentibulariaceæ*, *Bignoniaceæ*, *Acanthaceæ*, *Gesneraceæ*, *Orobanchaceæ*, *Globulariaceæ*, *Plantaginaceæ*, *Myoporaceæ*, *Verbenaceæ*, *Labiataæ*, *Oleaceæ*, *Jasminaceæ*.

Annual or perennial herbs, shrubs, and trees. Flowers actinomorphic and zygomorphic, hermaphrodite and pseudo-hermaphrodite. Floral-leaves in two 4-5-partite whorls; the lower whorl in the form of a calyx, the upper in the form of a corolla. Petals united. Gynæceum 2- or more celled, ovary superior. The ovules are developed either on the turned-in margins of the carpels or on an axile placenta. The androecium is composed of a whorl of 2-5 stamens. The fruit is either a succulent berry, a capsule with various modes of dehiscence, or a drupe.

The Solanaceæ, Scrophulariaceæ, Loganiaceæ, and Asclepiadaceæ contain poisonous alkaloids, the Gentianaceæ contain bitter substances, and the Labiataæ contain etherial oils and aromatic substances. The majority of Tubifloræ possess green foliage-leaves. Some Scrophulariaceæ, *e.g.* the species of the genus *Rehmannia*, are

in the form of switch-shrubs, and several *Asclepiadaceæ*, *e.g.* the species of the genus *Stapelia*, have cactiform stems. In these the assimilation of carbon is effected by the green cortical tissue. The *Orobanchaceæ* are parasites destitute of chlorophyll (see vol. i. p. 183). Amongst *Convolvulaceæ*, and more especially amongst *Scrophulariaceæ*, there are many species which live as parasites and saprophytes, and are partially deficient in chlorophyll (see vol. i. pp. 171–183). An account has already



Fig. 434.—*Acanthaceæ*.

Acanthus mollis on the coast of Dalmatia.

been given of the way in which the *Lentibulariaceæ*, *e.g.* the species belonging to the genera *Utricularia* and *Pinguicula*, derive a portion of their food from the bodies of insects which are caught by them (see vol. i. pp. 120, 140). In *Gentianaceæ*, *Oleaceæ*, *Apocynaceæ*, *Asclepiadaceæ*, *Convolvulaceæ*, and many *Boraginaceæ* and *Solanaceæ* the corolla is actinomorphic. The *Labiataæ*, *Scrophulariaceæ*, *Verbenaceæ*, *Acanthaceæ*, *Lentibulariaceæ*, and some genera of *Boraginaceæ* and *Solanaceæ* bear distinctly zygomorphic flowers. In the Ash genus (*Fraxinus*), which belongs to the family of *Oleaceæ*, the corolla is often entirely suppressed. Most *Labiataæ* have four

didynamous stamens, but some of them, *e.g.* those of the genus *Salvia* (see fig. 271, p. 262), have two stamens, as have also the species of the genus *Veronica* (see fig. 257, p. 226) of the family Scrophulariaceæ, and the majority of the Jasminaceæ and Oleaceæ (see fig. 283²). Most of the Tubifloræ possess five stamens. The curious modification of the andrœcium of Asclepiadaceæ has been fully described on p. 257,



Fig. 435.—Ranunculacæ.

¹ *Helleborus niger* (reduced $\frac{1}{2}$). ² *Myosurus minimus*, complete plant with flowers and flower-buds (nat. size). ³ A single flower of *Myosurus* (magnified).

et seq. In the Apocynaceæ the two opposite carpels are separate at the base and connate at the upper end only. The fruit of Labiatæ and Boraginaceæ resolves itself when it is ripe into four one-seeded nutlets. The seeds of Apocynaceæ and Asclepiadaceæ are furnished with a plume of hairs. In most of the Tubifloræ the base of the pistil is partially or completely surrounded by swollen tissue which

secretes honey. The Tubifloræ are distributed in every quarter of the globe. Several families, such as the Loganiaceæ and Bignoniaceæ, are confined to tropical and sub-tropical regions. The Acanthaceæ also chiefly inhabit the warmer parts of the earth. The genus *Acanthus* grows particularly in the region of the Mediterranean Flora. The leaves of several species of *Acanthus*, e.g. *Acanthus spinosissimus* (see vol. i. fig. 116, p. 437) and *Acanthus mollis* (see fig. 434), frequently served the Greek and Roman sculptors as patterns for their ornaments. The genus *Stapelia*, of the family Asclepiadaceæ, is confined to the Cape; the Labiatæ are most abundantly represented in the Mediterranean Flora; the Gentianaceæ and Scrophulariaceæ inhabit mountainous regions of the Old and the New World in large numbers of different forms, and several species of the genera *Gentiana*, *Veronica*, *Euphrasia*, and *Pedicularis* thrive best in proximity to glaciers both in mountain districts and in the arctic regions. Fossil remains occur in the strata of the Tertiary period. The number of species now living which have been identified up to the present time is about 16,500.

Class III.—POLYPETALÆ.

Alliance LIII.—Ranales.

Families: *Ranunculaceæ*, *Dilleniaceæ*, *Calycanthaceæ*, *Magnoliaceæ*, *Anonaceæ*, *Menispermaceæ*, *Berberidaceæ*, *Lardizabalaceæ*, *Nymphæaceæ*.

Stamens rarely definite. Carpels, free or immersed in the receptacle, very rarely connate. Embryo minute, embedded in a fleshy endosperm. In the *Ranunculaceæ* the petals are not infrequently modified into honey-glands, and the sepals petalline. The carpels are free from one another, and sometimes indefinite and spirally arranged, sometimes definite and whorled. In *Calycanthus*, the parts of the flowers are inserted in a continuous spiral upon a hollow receptacle, and pass gradually the one into the other. In *Berberidaceæ*, the anthers open by means of valves. The *Nymphæaceæ* include marsh and water plants (e.g. *Nymphæa*, *Nuphar*, *Nelumbium*, cf. fig. 436, *Victoria Regia*, Plate XI.). In several of these the carpels are united together into a large ovary with shield-like stigmatic disc. In *Nelumbium* (cf. fig. 334, p. 440), the carpels are borne in distinct sockets. The fruit in the alliance is very varied, and includes achenes, follicles, berries. Fossil remains occur in the Tertiary Strata. Total number of living species about 3000

Alliance LIV.—Parietales.

Families: *Sarraceniaceæ*, *Papaveraceæ*, *Fumariaceæ*, *Cruciferae*, *Capparidaceæ*, *Moringaceæ*, *Resedaceæ*, *Cistineæ*, *Violaceæ*, *Bixaceæ*.

Annual and perennial herbs, shrubs, and trees. Flowers solitary or in spikes, umbels, racemes, and racemose cymes; actinomorphic and zygomorphic, hermaphrodite and pseudo-hermaphrodite. Floral-leaves differentiated into calyx and corolla; the calyx composed of a 2-5-partite whorl, the corolla of two 2-partite

whorls or one 5-partite whorl. Petals free. Gynæceum composed of 2, 3, or several carpels joined together to form a unilocular (or spuriously bilocular), free, superior ovary. Ovules attached to the interior walls of the carpels on ridges, or springing directly from the walls of the ovary (see fig. 437¹). The androecium is composed of either one whorl or many whorls of 2–5 stamens; the stamens are free, and generally of equal length, and are not joined together or to the corolla (see fig. 243, p. 168). The fruit, in most cases, is a many-seeded capsule (see fig. 437²); in the genus *Fumaria* it is a small one-seeded drupe (see figs. 322¹ and 322², p. 427).



Fig. 436.—*Nelumbium speciosum*, the Indian Lotus, growing in a marah, near Pekin (from a photograph).

In the Capparidaceæ, it is borne on a long stalk. The Resedaceæ are interesting, in that in many of them the ovary is open from the beginning, the stigmatic tissue being formed by the swollen lips. The Cruciferae form a large and important family of over 200 genera. For systematic purposes they are divided into the following tribes:—Pleurorhizeæ, Notorhizeæ, Orthoplocææ, Spirolobææ, and Diplocolobææ. Annual or perennial herbs and suffrutices with the foliage-leaves in spirals, venation pinnate. Flowers in racemes, hermaphrodite, pseudo-hermaphrodite, actinomorphic and zygomorphic. Floral-leaves differentiated into calyx and corolla, each of which is composed of two 2-merous whorls. Petals free. Ovary free, superior. The carpels spring from below the end of the conical receptacle, and are of two kinds: the two lower carpels bear no ovules, but form valves, whilst the two

upper are transformed into ribs and form a framework to which the valves are applied. The two superior carpels are separated by a thin membrane, and bear the ovules in two rows (see p. 75). The androecium is composed of two short and four long stamens (see p. 292, fig. 284⁸). The pollen is adhesive. The fruit is a silique (see p. 75 and p. 431, fig. 325^{15, 16}). The seeds have no endosperm. The embryo

is curved. The cotyledons and also the foliage-leaves and roots of most Cruciferæ contain pungent and oily substances, particularly Oil of Mustard, as is well known in the cases of the Mustard-plant, Water-cress, Garden-cress, Radish, and Horse-radish.

The Cruciferæ are distributed over the Northern Hemisphere. They occur in greatest variety in the steppe-districts of the Old World. The Mediterranean, Arctic, and Alpine floras also include large numbers of these plants. Amongst those Phanerogams which survive at the very confines of vegetation in the Arctic regions, and on mountains, are to be reckoned several Cruciferæ. No fossil remains are known.

The Sarraceniaceæ are marsh- and water-plants, and their leaves are adapted to the capture of insects (see vol. i. p. 143 *et seq.*), whilst the rest of the Parietales grow chiefly on rocky or sandy ground. The Parietales are distributed over the warm and temperate parts of the Old and the New World; the Cistaceæ belong especially to the flora of the Mediterranean. The only known instance of fossil remains is the fruit of a Poppy which was found in a deposit of the Tertiary Period. The number of extant species hitherto identified is about 3000.

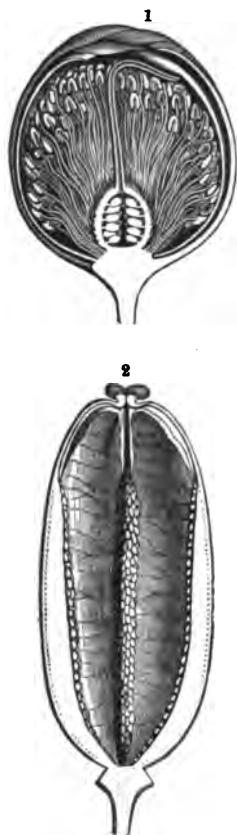


Fig. 437.—Parietales.

¹ *Bixa Orellana* (Bixaceæ). Longitudinal section through a flower-bud which is about to open. ² *Argemone Mexicana* (Papaveraceæ). Longitudinal section through the ovary. (Magnified.)

Alliance LV.—Malvales.

Families: *Malvaceæ*, *Sterculiaceæ*, *Tiliaceæ*.

Flowers actinomorphic, parts in whorls of 5. Sepals free or connate, often valvate in bud. Stamens various, often united. Carpels 3 to indefinite, united. Placentation axile; seeds with endosperm. The Malvaceæ often possess an epi-calyx; fruit usually splitting into 1-seeded mericarps. They include the Mallows (*Malva*), Cotton-plants (*Gossypium*), Hollyhock (*Althæa*), &c. The Tiliaceæ are represented by the Linden (*Tilia*), and the Sterculiaceæ include *Theobroma Cacao*, from which chocolate is derived.

There are nearly 200 species in this alliance.

Alliance LVI.—Discifloræ.

Families: *Linaceæ*, *Erythroxylaceæ*, *Oxalidaceæ*, *Humiriaceæ*, *Malpighiaceæ*, *Zygophyllaceæ*, *Geraniaceæ*, *Balsamineæ*, *Tropæolaceæ*, *Rutaceæ*, *Aurantiaceæ*, *Diosmaceæ*, *Zanthoxylaceæ*, *Simarubaceæ*, *Ochnaceæ*, *Burseraceæ*, *Meliaceæ*, *Ilicineæ*, *Celastrineæ*, *Rhamnaceæ*, *Ampelideæ*, *Sapindaceæ*, *Acerineæ*, *Hippocastaneæ*, *Sabiaceæ*, *Terebinthaceæ*.

Annual and perennial herbs, shrubs, and trees, with simple and compound foliage-leaves. Flowers actinomorphic and zygomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious and diœcious; arranged in varying types of inflorescence. Floral-leaves in two 4-5-merous whorls; the lower whorl a calyx, the upper a corolla. The gynæceum is composed of a whorl of carpels borne on a swollen disc. Ovary superior. Each carpel has a separate loculus. In *Aurantiaceæ* and *Ampelideæ* the carpels are completely united so as to form a single pistil; in *Rutaceæ* and *Zygophyllaceæ* they are united at the base and form a lobed ovary, whilst in *Zanthoxylaceæ*, *Ochnaceæ*, and *Simarubaceæ*, they are quite separate (see fig. 438⁶). In *Terebinthaceæ* only one carpel is developed, but there are usually traces of suppressed carpels close to it. The ovules are in the inner angles of the loculi; in *Aurantiaceæ*, *Rutaceæ*, and *Zygophyllaceæ* their number exceeds two in each loculus, in the other families it is only 1-2. The stamens are arranged in 1-2 whorls, and number 4-5 in each whorl; they spring from the edge or from the surface of the floral receptacle, which is swollen and forms a ring round the ovary; their place of origin is always lower than the base of the ovary (see figs. 438^{2,5,7}). The pollen is adhesive. The fruit contains either few seeds or a single comparatively large seed.

The *Discifloræ* are in most instances woody plants, containing etherial oils and aromatic, resinous substances like turpentine. Amongst the *Malpighiaceæ*, *Celastrineæ*, and *Ampelideæ* are many lianes. The foliage-leaves are undivided in *Erythroxylaceæ* and *Celastrineæ* (see fig. 438¹), lobed in most *Aceraceæ* and *Ampelideæ*, and variously segmented and compounded in the other families (see fig. 438³). The petals are usually small, and of a greenish-yellow colour. The filaments in *Melanthaceæ* and *Aurantiaceæ* are connate all together, or in groups. The fruits are extremely various. In *Staphyleaceæ* and *Diosmaceæ* they are follicles; in *Celastraceæ* and *Rutaceæ*, capsules (see fig. 325⁶, p. 431); in *Zygophyllaceæ*, *Aceraceæ*, and *Malpighiaceæ*, schizocarps; in the Tree of Heaven, of the family *Simarubaceæ*, winged achenes (samaras, see fig. 323⁷, p. 428); and in *Ampelideæ* and *Aurantiaceæ*, berries. The *Discifloræ* are distributed over the whole earth. The majority belong to the tropics, and several, e.g. *Burseraceæ*, *Ochnaceæ*, and *Malpighiaceæ* are exclusively tropical. The *Diosmaceæ* are confined to South Africa, the *Rutaceæ* to the districts of the Mediterranean and the Black Sea. Comparatively few species occur in the Northern Temperate Zone, or in corresponding situations on mountains. The Mountain Maple covers about the



Fig. 488.—Discifloræ.

¹ *Euonymus Europæus* (Family Celastrinæ), flowering branch. ² Longitudinal section through a flower. ³ *Quassia amara* (Family Simarubacæ), flowering branch. ⁴ Gynoecium and floral receptacle. ⁵ *Ochna* (Family Ochnacæ), receptacle, gynoecium, and one stamen. ⁶ Fruit of same. ⁷ Longitudinal section through the flower of the Tree of Heaven (*Ailanthus*, family Simarubacæ). (Partly after Baillon.)

same ground as the Beech, and, in the Central Alps, even extends beyond the upper limit of the Beech. Fossil remains are found in the Mesozoic and Tertiary strata. The number of known species now living is about 9000.

Alliance LVII.—Crateranthæ.

Families: *Leguminosæ*, *Rosaceæ*, *Saxifragaceæ*, *Escalloniaceæ*, *Cephalotaceæ*, *Francoaceæ*, *Crassulaceæ*, *Hydrangeaceæ*, *Ribesaceæ*, *Philadelphaceæ*, *Styracaceæ*, *Hamamelidaceæ*, *Rhamnaceæ*.

Annual and perennial herbs, shrubs, and trees. Flowers abundant; actinomorphic and zygomorphic; hermaphrodite, pseudo-hermaphrodite, monœcious, and dicecious. Floral-leaves in two 4-5-merous whorls, the lower whorl a calyx, the upper a corolla. Both whorls spring from the pitcher-shaped, bowl-shaped, or flat hypanthium, the petals always from the edge, the sepals, in part, also from the base of the hypanthium. In the last case the tube of the calyx is adnate to the external surface of the hypanthium. The gynæceum is in the middle of the hypanthium, and consists either of a single carpel with a unilocular ovary (see figs. 438*^{1,3,4}), or of several separate unilocular carpels (see fig. 438*², and p. 74, fig. 208²), or of 2-many united carpels inclosing a multilocular ovary which may be adnate to the surrounding hypanthium at the base only, or from the base to the middle, or from the base to the top (see p. 74, fig. 208^{4,5,6}). The ovules are situated on the ventral suture, and therefore in the inner angles of the loculi. The stamens spring from the edge of the hypanthium (see fig. 438*), and are in 1-2 whorls of 3-5 members each. The fruit is very various (pod, follicle, drupe, nut, berry, &c.), and the diversity in this respect affords the best means of distinguishing the numerous families belonging to this alliance. The hypanthium also varies considerably, and

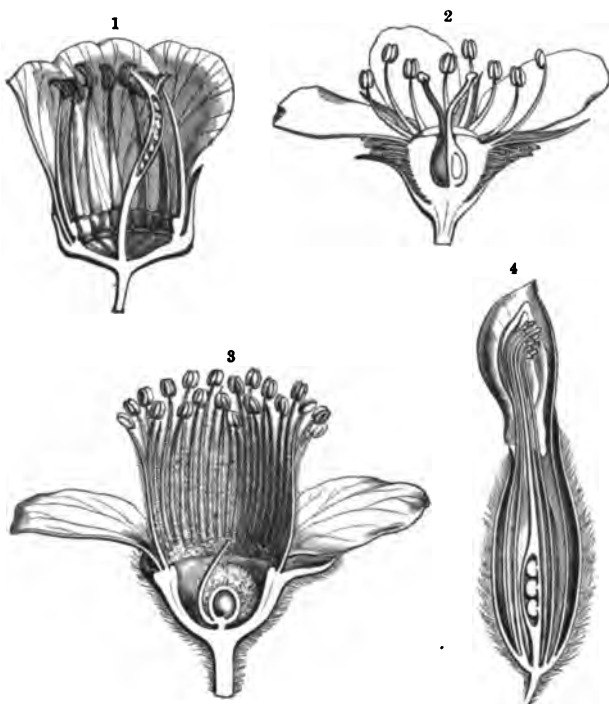


Fig. 438*.—Crateranthæ.

Longitudinal sections through the flowers of: 1 *Cadia varia* (Family Leguminosæ, division Cassalpines). 2 *Agrimonia Eupatorium* (Family Rosaceæ, division Agrimoniaceæ). 3 *Chrysobalanus* (Family Rosaceæ, division Chrysobalanaceæ). 4 *Anthyllus Vulneraria* (Family Leguminosæ, division Papilionaceæ). (After Ballou.)

the families above enumerated may be placed in several groups according to the form of that structure. In the first group the hypanthium is short as compared with the floral-leaves, and dries up or detaches itself when the fruit is ripe (Papilionaceæ, Cæsalpinæ, Mimoseæ, Amygdaleæ, Rhamnaceæ); the pistil is simple. In the second group the hypanthium is flat, and bears the floral-leaves and stamens on its margin, and several separate unilocular carpels arranged in spirals in the middle of its surface; it does not fall off when the fruit ripens. In the third group the hypanthium undergoes further growth when the fruit ripens, and is converted into an envelope surrounding the nut-fruits, which have developed from the separate carpels in the interior of the pitcher-shaped cavity of the hypanthium (Agrimoneæ, Roseæ; see fig. 438*², and fig. 208^{1, 2} p. 74). In the fourth group the multilocular pistil is adnate to the hypanthium which surrounds it entirely, and is converted into a fleshy pericarp (Pomaceæ; see fig. 208^{4, 5, 6} p. 74). In the fifth group only the lower half of the 2-carpellary gynæceum is adnate to the hypanthium, so that its upper half projects above the hypanthium, which is clothed by the calyx-tube (some of the Saxifragaceæ). In the sixth and last group the short hypanthium is only adnate at the base to the multicarpellary, actinomorphic gynæceum (Crassulaceæ, Styracaceæ, &c.). These groups are by no means sharply defined, and the links connecting them are again described as special families. It is also worthy of note that honey-secreting tissues in the flowers exhibit extreme variety of form and position; sometimes they constitute a fleshy lining to the inner, i.e. the upper-surface of the hypanthium (several Dryadeæ), sometimes a swelling round the base of the ovary (several Saxifragaceæ), sometimes an annular ridge, or a group of separate wart-like glands, which are seated on the edge of the extremely short hypanthium, and are looked upon as metamorphosed stamens (Crassulaceæ).

Amongst Cæsalpinæ, Pomaceæ, and Hamamelidaceæ are many species of arboreal growth, and amongst Mimoseæ, Amygdaleæ, Roseæ, Spirææ, Rhamnaceæ, and Hydrangeaceæ are large numbers of shrubs and under-shrubs. The majority of the herbaceous plants of this alliance occur in the families of Papilionaceæ, Dryadeæ, Agrimoneæ, and Saxifragaceæ. The Cæsalpinæ include several climbing lianes, the Papilionaceæ afford numbers of instances of switch-shrubs, and the Mimoseæ exhibit many shrubs with phyllodes. Amongst the Saxifragaceæ and Crassulaceæ many species with thick leaves (see vol. i. p. 327) occur. *Cephalotus* is insectivorous (see vol. i. p. 131). Compound pinnate or digitate foliage-leaves occur especially in Rubæ, Dryadeæ, Roseæ, Papilionaceæ, Cæsalpinæ, and Mimoseæ (see vol. i. p. 533), whilst entire foliage-leaves are found particularly in Amygdaleæ, Styracaceæ, Crassulaceæ, Philadelphaceæ, and Rhamnaceæ. The flowers of Papilionaceæ and Cæsalpinæ, and of some of the Saxifragaceæ and Chrysobalanæ, are zygomorphic; those of the other families are actinomorphic. In some Mimoseæ, Crassulaceæ, and Styracaceæ the petals are connate at the base. Small, inconspicuous, greenish petals are exhibited by some Agrimoneæ, Dryadeæ, Saxifragaceæ, Crassulaceæ, and by many Hamamelidaceæ and Rhamnaceæ; but most of the species of the alliance *Crateranthæ* have brightly-coloured petals. Dusty pollen has

only been observed in a very few species (e.g. *Poterium*). In some Dryadaceæ and Chrysobalanæ the style springs in a curious manner from the base of the ovary (see fig. 438*^s). The fruit is a pod (legume) in Papilionaceæ, Cæsalpinæ, and Mimoseæ, and these three sub-families are hence often classed together by botanists under the name of Leguminosæ. The fruit of Amygdalæ, Chrysobalanæ and Rubæ is a 1-stoned drupe, that of Rhamnaceæ a 3-stoned drupe. The Agrimonæ and Dryadæ are distinguished by small nut-like fruits, and the Spirææ, Saxifragaceæ, and Crassulaceæ have follicles which dehisce at the upper part of the ventral suture. In most of the families above enumerated the seeds contain no endosperm; on the other hand, the thick cotyledons are crammed with reserve materials, and several of these seeds are used as important articles of human food (e.g. beans, peas, lentils, &c.).

The Crateranthæ are distributed in all quarters of the globe and in all latitudes. Cæsalpinæ and Chrysobalanæ belong chiefly to the tropics, whilst Dryadæ and Saxifragaceæ live principally in the arctic regions and on high mountains. The Papilionaceæ are found most abundantly in the area of the Mediterranean flora and in the steppes in the south-west of Asia. More than 800 species of the genus *Astragalus* alone are known to exist in the last-mentioned districts. The Mimoseæ, especially the species of the genus *Acacia*, are represented in Africa and Australia by many characteristic forms. Roseæ and Rubæ, e.g. the genera *Rosa* and *Rubus*, occur in an astonishing variety of species in Central Europe, whilst the Spirææ and Amygdalæ are in like abundance in the west of Asia. Crassulaceæ are most abundant at the Cape and in Mexico, but they are also represented by a great number of species of the genus *Sempervivum* in the mountainous parts of Southern Europe. *Rhodiola rosea*, which belongs to this family, occurs in the arctic flora, and *Sedum repens* is found in the Alps at a height of 3000 metres above the sea. Of the Saxifragaceæ, *Saxifraga oppositifolia* reaches the furthest north, it having been met with at the northernmost spot hitherto visited in Franz Joseph's Land, at 81° N. Lat. In the Central Alps this Saxifrage is found at an elevation of 3160 metres. Fossil remains of Rosaceæ, Leguminosæ, and Rhamnaceæ have been identified in the deposits of the Tertiary Period. The number of extant species hitherto discovered amounts to about 10,000.

Alliance LVIII.—Myrtales.

Families: *Myrtaceæ*, *Granataceæ*, *Onagraceæ*.

Annual and perennial herbs, shrubs, and trees, with entire foliage-leaves. Venation consisting of a main axial strand, with sinuous lateral strands branching pinnately from it. Flowers hermaphrodite, actinomorphic or zygomorphic. The floral-leaves spring from an annular or tubular hypanthium, which is fused with the inferior ovary; they are differentiated into calyx and corolla, each of which consists of a 2-6-merous whorl. The stamens are in 1, 2, or more whorls of 2-6 members

each, and spring from the fleshy annular or tubular hypanthium which rises up above the ovary. The fruit is baccate, drupaceous, or capsular.

The *Granataceæ* and *Onagraceæ* contain watery juices, whilst the species belonging to the other families are more or less rich in aromatic substances and etherial oils. Several are used as spices. Allspice is derived from *Pimenta officinalis*, and cloves are prepared from the flower-buds of *Eugenia caryophyllata*. The *Circææ* are small and delicate herbs, the *Chamælaucææ* are dwarf shrubs; whilst the genus *Eucalyptus* of the family *Myrtaceæ* includes several species which are amongst the highest trees in the world (see vol. i. p. 723). The flower in *Circæa* exhibits two sepals, two petals, and two stamens in order (see fig. 261⁸, p. 236). In *Ænothera* and *Epilobium* the calyx and the corolla are composed of one 4-partite whorl each, and the andrœcium of 2 such whorls (see fig. 281, p. 282, and fig. 300, p. 354). In *Eucalyptus*, *Myrtus*, and many other genera the number of stamens amounts to over

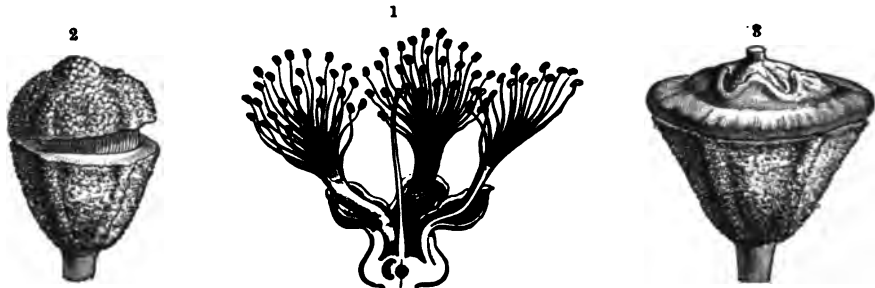


Fig. 439.—Myrtaceæ.

¹ *Melaleuca*. Longitudinal section through the flower. ² Flower-bud of *Eucalyptus globulus*; the connate sepals are detached from the receptacle as a lid when the bud opens. ³ Fruit of *Eucalyptus globulus*. (After Baillon.)

100; in *Melaleuca* (see fig. 284⁴, p. 292) the stamens are coherent in bunches. Where the petals are suppressed, the filiform filaments are white or bright red and yellow. In the *Fuchsias* the sepals are coloured like petals; in some species of the genus *Eucalyptus* the sepals, which are joined together so as to form a lid, become detached from the floral receptacle before the flower opens. This remarkable phenomenon is shown in fig. 439². The hypanthium which invests the ovary exhibits every possible transition in form, from a shallow saucer to a long tube (see fig. 266, p. 247). The ovary is in several families divided by septa, composed of tissue pertaining to the receptacle, which extend from the central column to the wall of the ovary. In *Granataceæ* (*Punica Granatum*) the ovary is in addition divided by a plate of tissue into an upper and a lower story, and placentas are developed in the chambers of both stories. The fruits of several *Lecythidaceæ*, e.g. those of *Lecythis*, open with a lid; those of *Eucalyptus* are in the form of hard woody capsules, which dehisce at the top by means of valves, pores, or slits (see fig. 439³). The fruits of *Circæa* are indehiscent; those of *Epilobium*, &c., are capsular, and open by valves. Many *Myrtaceæ* and the *Fuchsias* have baccate fruits. The fruit of the Pomegranate (*Punica Granatum*) resembles an apple. The seeds of *Bertholletia excelsa* of the family *Lecythidaceæ* are known as Brazil nuts, and have a coat as hard as stone;

those of the Pomegranate have a fleshy coat, and those of *Epilobium* are furnished with hairs. The Myrtales are distributed over all quarters of the globe. The Chamælaucæ and Leptospermaceæ are natives of Australia and the islands of the Pacific Ocean. Several species of this family help to form Australian bush, whilst others, especially species of the genus *Eucalyptus*, constitute entire forests (see Plate XVI.). The Lecythidaceæ grow chiefly in South America. The Myrtaceæ are most abundant in America, and occur also in Asia and Africa. Europe only possesses one species, *Myrtus communis*, which belongs to the Mediterranean Flora. The Fuchsias are indigenous to Central and South America. The Epilobiums and



Fig. 440.—Melastomaceæ.

Melastoma Malabathricum. (After Baillon.)

Circæas live principally in the North Temperate Zone, and some species of the genus *Epilobium* occur in the arctic regions and on mountain heights. Fossil remains of Myrtaceæ and Granataceæ have been found in the strata of the Tertiary Period. The number of species ascertained to exist at the present day is about 2500.

Alliance LIX.—Melastomales.

Family: *Melastomaceæ*.

Perennial herbs, shrubs, and trees, with opposite or whorled foliage-leaves. Leaves entire, with 3–11 curved ribs connected by transverse anastomoses (see fig. 440). Flowers hermaphrodite or pseudo-hermaphrodite; slightly zygomorphic. Floral-leaves differentiated into calyx and corolla. The bowl-shaped or tubular

receptacle is covered externally by the tube of the 4-6-sepalous calyx, is surmounted by the segments of the calyx-limb, and bears upon it the 4-6 petals which alternate with those segments. The gynæceum is composed of 3-8 connate carpels. The 3-8-locular ovary is adnate to the hollowed receptacle at the base only, or from the base to the middle, or from the base to the top. An axis rises up in the middle of the ovary and bears the placentas, which project into the separate loculi. The androecium is composed of 1-2 whorls of 4-5 stamens each. At the base of each anther is a spur-like appendage; dehiscence is apical by 1 or 2 small holes (see fig. 216¹³, p. 91). The pollen is powdery. The fruit is a berry or a capsule which dehisces by valves. The seeds contain no endosperm.

The Melastomales belong chiefly to tropical America. Fossil remains have not been identified with certainty. The number of species ascertained to exist at the present time is about 2000.

Alliance LX.—Lythrales.

Families: *Lythraceæ*, *Cupheaceæ*, and *Lagerstroemiaceæ*.

Annual or perennial herbs, shrubs, and trees with opposite or whorled foliage-leaves. Laminæ entire, with pinnate venation. Flowers hermaphrodite, actinomorphic or zygomorphic, with calyx and corolla. The cup-shaped or tubular receptacle is covered externally by the tube of the 3-16-sepalous calyx, the segments of which project beyond it and alternate with the 3-16 petals which are borne upon the receptacle. The gynæceum is composed of 2-6 connate carpels. The 2-6-locular ovary is free, and is situated at the bottom of the hollow receptacle. An axial column rises up in the middle of the ovary and bears the placentas, which project into the separate loculi. The androecium is composed of 1-2 whorls of 3-16 stamens each. The anthers have no appendages, and dehisce by longitudinal slits. The pollen is adhesive. The fruit is a capsule coated by the cup-shaped receptacle. The seeds contain no endosperm.

The Lythrales are distributed in all quarters of the globe. They exhibit greatest variety in tropical America. In the North Temperate Zone they are represented by the genera *Lythrum*, *Peplis*, and *Didiplis*. No fossil remains are known. The number of identified species now living is about 400.

Alliance LXI.—Hydrobia.

Families: *Hippuridaceæ*, *Callitrichaceæ*, *Myriophyllaceæ*, *Gunneraceæ*, *Trapaceæ*.

Herbs and under-shrubs living in water or in wet places. Flowers hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious; actinomorphic. Floral-leaves inconspicuous, in 1-2 whorls of 2-4 leaves each. Gynæceum of one carpel or 2-4 connate carpels. The under half or the whole of the 1-4-locular ovary is adnate to the sepals, which cohere so as to form a cup. Each loculus contains one ovule in its inner angle. The androecium is composed of 1-8 stamens. The fruit is

a schizocarp (*Callitriche*; see p. 427, figs. 322³ and 322⁴) or a drupe covered with a thin coat of pulp; it becomes detached from the receptacle. In the Water Chestnut (*Trapa natans*; see vol. i. p. 607, fig. 144) the two whorls of two sepals each which are adnate to the ovary become a part of the fruit, and their apices project in the form of four stiff points. The Hygrobiæ are distributed in every quarter of the globe, but belong especially to the North Temperate Zone. The Gunneraceæ inhabit the Southern Hemisphere. Fossil remains of a plant resembling *Myriophyllum* have been found in strata of the Tertiary Period. The number of extant species known is about 100.

Alliance LXII.—Passiflorales.

Families: *Passifloraceæ*, *Loasaceæ*, *Datiscaceæ*, *Samydaceæ*, *Turneraceæ*,
Papayaceæ.

Annual or perennial herbs, shrubs, and trees, with palmately-lobed foliage-leaves. Venation palmate (radiating). Flowers hermaphrodite or pseudo-hermaphrodite, and dioecious; actinomorphic. The floral-leaves spring from a cup-shaped hypanthium in one or two 4-5-merous whorls. The gynæceum is composed of 3 connate carpels. The unilocular ovary is free, and is raised upon a more or less elongated stalk from the bottom of the receptacle, or else it is sessile and adnate to the cup-shaped receptacle either half-way from the base or from base to top. The ovules are borne upon three placentas which project in the form of cushions from the internal wall of the ovary. The andrœcium is composed of 4-5 stamens which spring from the edge of the cup-shaped hypanthium. The fruit is a berry or a capsule opening by valves. The seeds contain a fleshy endosperm, in which is imbedded a straight embryo.

The *Datiscaceæ* have a sepaloid perianth. In the *Loasaceæ* and *Passifloraceæ* the floral-leaves are in two whorls, both of which are petaloid. In the *Passifloraceæ* a many-membered corona is inserted between the andrœcium and the petals. The *Passiflorales* belong chiefly to tropical America. Fossil remains have not been identified with certainty. The number of extant species known is about 700.

Alliance LXIII.—Pepones.

Families: *Cucurbitaceæ* and *Begoniaceæ*.

Annual and perennial herbs and under-shrubs (suffrutices). Venation of the foliage-leaves radiating (palmate). Flowers solitary or in cymes; actinomorphic; pseudo-hermaphrodite, monoecious and dioecious. The uppermost part of the receptacle, which is deeply hollowed, is developed as a hypanthium, and from it spring the floral-leaves in 1-2 whorls of 2-5 segments each. When two whorls are present they are either both petaloid in colour or the under whorl is a calyx and the upper a corolla. The petals are either free or partially coherent. The ovary is inferior. The ovules are borne on thick pads which are split in two longitudinally,

and project into the middle of the ovary. The androecium is composed of 5 or many stamens which spring from the hypanthium, and are joined at the base to the corolla. The fruit is baccate or capsular. The seeds contain no endosperm.

The Cucurbitaceæ have symmetrical foliage-leaves—no stipules, but often tendrils (see vol. i. p. 696, fig. 165); the Begoniaceæ have oblique, unsymmetrical laminae, large lacerated stipules, and no tendrils (see vol. i. p. 420, fig. 110¹). The whorls of floral-leaves are 5-merous in Cucurbitaceæ; in Begoniaceæ the floral-leaves of the female flowers are arranged in two whorls of 3–5 segments each, and those of the male flowers in two whorls of 2–5 segments each. Three winged ridges project from the inferior ovary in Begoniaceæ. The stalks of the ovules of Cucurbitaceæ fill the cavity of the ovary so completely that only small interstices are left between them. In many Cucurbitaceæ these stalks are converted when the seeds ripen into a succulent mass (e.g. in cucumbers, melons, and gourds). In Begoniaceæ also they project from the walls into the middle of the ovary, and the latter looks in consequence as if it were divided into loculi. The androecium exhibits great diversity. In some Cucurbitaceæ the five stamens are free; in others they are partially united, and in a third group they are all completely fused together into a column. In Begoniaceæ, also, the stamens are connate and form a column. In many cases the anthers are sinuous, and in the genus (*Cyclanthera*) there is a continuous anther all round the column. The Pepones are mainly tropical plants. The Begoniaceæ grow especially in the tropical forests of America, where they are not infrequently epiphytic. There is still some doubt as to the place of origin of Melons, Gourds, and Cucumbers. The alliance is represented by the Squirting Cucumber (*Elaterium*) in the South of Europe, and by Bryony (*Bryonia*) in Central and Northern Europe. No fossil remains have been discovered. The number of extant species hitherto identified is about 1100.

Alliance LXIV.—Cactales.

Families: *Opuntiaceæ* and *Cactaceæ*.

Perennial plants, whose stems are much swollen or flattened. Flowers solitary; actinomorphic or zygomorphic; hermaphrodite. The ovary consists of a hollow, cup-shaped floral receptacle, from the inner wall of which spring filiform stalks bearing the ovules (see fig. 209^{1, 2}, p. 77). The external surface of the receptacle is clothed by floral-leaves arranged in a spiral; the lower leaves are small and inconspicuous, the upper petaloid and brightly coloured (see figs. 441^{1, 2, 3, 4, 5}). Inside the upper tubular prolongation of the receptacle are crowds of stamens arranged spirally. The pollen is adhesive. The fruit is unilocular and succulent (see fig. 441²). The seeds contain no endosperm.

The genus *Pereskia* alone exhibits thick, green foliage-leaves; in the other genera the leaves are replaced by small caducous scales or thorns, and assimilation is effected by means of the green cortical tissue of the swollen stems (see vol. i. pp. 327 and 440). The species of *Rhipsalis* and *Phyllocactus*, which are epiphytic

on the branches of old trees, have much-branched and segmented phylloclades, which often hang in curves; the segments of the stem in *Opuntias* are laterally compressed, and more or less discoid (see vol. i. Plate IV.). The cylindrical stems of the Queen of Night (*Cereus nycticalus*, vol. i. Plate VII., in foreground) are prismatic, and climb up rocks and the bark of trees by means of clinging roots. Other species of *Cereus*, such as *Cereus giganteus*, which grows to a height of 20 metres, possess erect columnar stems (Plate VII., left hand, middle distance). Another set of *Cereus*-species, including the many forms of *Mammillaria*, *Melocactus*, *Echinocactus*, and *Echinopsis*, are spherical or truncate; they are covered either with papillæ, each of which is crowned by a bunch of prickles (see fig. 441³), or

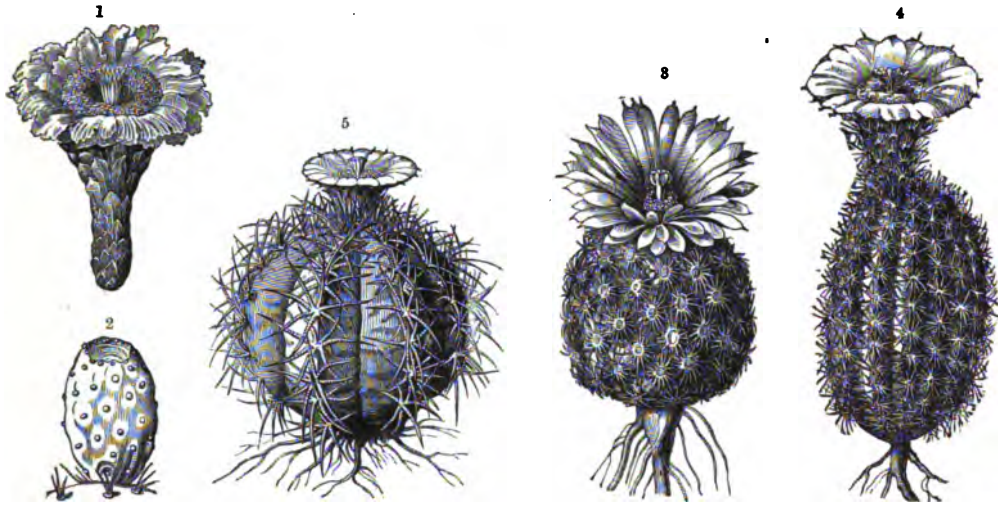


Fig. 441.—Cactaceæ.

¹ Flower. ² Fruit of *Cereus giganteus*. ³ *Mammillaria pectinata*. ⁴ *Cereus dasyacanthus*. ⁵ *Echinocactus horizontalis*. All the figures reduced.

with tubercles, which coalesce into crests and ribs (see figs. 441⁴ and 441⁵). The Cactuses are natives of the New World, and inhabit regions where a short, rainy season is followed by a prolonged period of drought. The largest number of species is found in Mexico. Some species also occur at high elevations in the Andes. No fossil remains are known. The number of species ascertained to exist at the present time is about 1300

Alliance LXV.—Ficoidales.

Families: *Portulacææ*, *Molluginaceæ*, *Ficoidaceæ*, *Mesembryanthemaceæ*.

Annual and perennial herbs and under-shrubs, with entire fleshy foliage-leaves. Flowers solitary or in fascicles and glomerules; actinomorphic, hermaphrodite. The floral-leaves free or else connate at the base; in one, two, or several 2-5-merous whorls. Either all the floral-leaves, or only those of the lowest whorl, are sepaloïd; in the latter case, the upper whorl or whorls are petaloïd. The

gynæceum is composed of 3, 5, 8 or more connate carpels. The ovary is adnate to the bowl-shaped receptacle at the base only or as regards the lower half of its surface, or from the base to the top; it is crowned by a radiating stigma of 3–10 rays, and is uni- or multi-locular. A column rises up in the middle of the ovary, and bears the ovules. In the case of multilocular ovaries, the ovules are borne on ridges and strands which project from this column into the loculi. The androecium is composed of one or several whorls of 3–10 stamens each. The anthers have no spurs, and they dehisce by longitudinal slits. The pollen is adhesive. The fruit is a capsule or an achene. The seeds contain a mealy albumen and a curved embryo.

The Ficoidales chiefly inhabit dry localities. Only a few species (e.g. *Montia fontana*) live in water and on marshy soil. They are distributed all over the globe. Most of the Portulacæ belong to South America and the Cape. The Mesembryanthemacæ are developed in extraordinary variety in South Africa. There are over 300 species of the genus *Mesembryanthemum* alone at the Cape. No fossil remains are known. The number of extant species hitherto identified is about 500.

Alliance LXVI.—Umbellales.

Families: *Cornacæ*, *Araliaceæ*, and *Umbelliferæ*.

Annual or perennial herbs, shrubs, and trees which flower profusely. Flowers in capitula, umbels, and cymes. Floral-leaves differentiated into calyx and corolla. The calyx 4–5 sepalous, with its tube clothing the inferior ovary and the limb represented by 4–5 small teeth, which surround the top of the ovary. The corolla is likewise 4–5 petalous, the petals free and alternating with the sepals. The gynæceum is composed of a whorl of connate carpels; ovary inferior, 2–5 locular. Every locus corresponds to a carpel, and contains a single ovule, which is suspended near the upper end of the locus (see fig. 442⁴). On the top of the ovary is a glandular disc, which secretes honey (see figs. 442^{2, 4, 7}). The androecium consists of a whorl of 4–5 stamens. The stamens are quite separate, and stand in a circle round the honey-secreting disc. The fruit in Umbelliferæ is a schizocarp (see p. 427, fig. 322^{5, 6, 7} and fig. 442³), in Cornacæ and Araliacæ a berry or drupe. The seed contains an abundant endosperm, in which the embryo is imbedded.

The Cornacæ are for the most part woody plants, with entire, opposite foliage-leaves, possessing a venation of arched strands (see p. 231, fig. 260 and vol. i. p. 630). The Araliacæ, of which the Ivy (*Hedera Helix*, see vol. i. p. 703, fig. 167) may be taken as a type, are woody plants with climbing roots, or shrubs and herbs with radiately-veined foliage, and the Umbelliferæ, which are very rich in aromatic substances, oils, and resins, are for the most part herbs whose stems in many species reach a length of 3–4 metres, as, for instance, in *Ferula communis* and *Euryangium Sumbul*. The foliage-leaves of Umbelliferæ are usually much divided (see fig. 442¹), those of *Hydrocotyle vulgaris*, a plant which lives in swamps, are peltate (see

fig. 442⁵). The calyx, corolla, and andrœcium are 4-merous in Cornaceæ, 5-merous in Umbelliferae and Araliaceæ (see figs. 442² and 442⁶, and p. 289, fig. 283⁴). The Umbellales belong chiefly to the North Temperate Zone, but the Araliaceæ are



Fig. 442.—Umbellales.

¹ *Heracleum Sphondylium* (Family Umbelliferae), flowering plant. ² Single flower. ³ Fruit. ⁴ Longitudinal section through the flower of *Bryngium maritimum* (Family Umbelliferae). ⁵ *Hydrocotyle vulgaris* (Family Umbelliferae), entire plant. ⁶ *Cornus mas* (Family Cornaceæ), inflorescence. ⁷ Longitudinal section through a flower. ⁸ Fruit. ², ³, ⁴, ⁶, ⁷, and ⁸ magnified. (After Baillon.)

also represented by a number of species in the Tropics. Several of the Umbelliferae are natives of the arctic area of vegetation and of alpine regions. *Gaya simplex* occurs in the Central Alps as high as 2600 metres above the sea-level. Fossil remains, belonging chiefly to the families of Araliaceæ and Cornaceæ, have been

found in the deposits of the Mesozoic and Tertiary Periods. The number of extant species identified hitherto amounts to about 1800.

4.—THE DISTRIBUTION OF SPECIES.

Distribution of Species by Offshoots.—Distribution of Species by Fruits and Seeds.—Limits of Distribution.—Plant-Communities and Floras.

THE DISTRIBUTION OF SPECIES BY OFFSHOOTS.

When the dreaded Dry-rot spreads unhindered over the surfaces of wooden beams, in a dark, damp cellar, its mycelium presents quite a strange appearance. Grouped in a circle around a dark centre of dead, disintegrating, and crumbling wood are a number of white spots, joined by indistinct lines to a centre. But this was not always the case. That which now forms the dead and crumbling centre was formerly the seat of the first development of the mycelium, then composed of a coherent network of mycelial threads and appearing to the naked eye as a single rounded white spot. The mycelial threads then crept out like rays all round the periphery, and as the white spot increased in diameter its centre became proportionately dark. The mycelial threads forsook their first settlement; they died off, and the wood they had destroyed then appeared merely as the dark centre of a white ring. In consequence of its continual widening the ring at length becomes segregated into stars, and is gradually transformed into a wreath of isolated mycelia, or, in other words, a group of separate but distinct mycelial spots arranged in a circle arises from a single mycelium in consequence of its radiating method of growth.

The mycelium of *Gasteromycetes*, of many *Fungi* allied to *Morels*, and especially of many *Agarics* growing in the forest mould or in meadow humus, also exhibit under favourable conditions this ring and wreath formation. Although it is not possible to see the subterranean growth directly, its results are readily recognizable, since the receptacles rise above the ground from the separate portions of mycelium and indicate their distribution; these receptacles occur in regular circles, and when their colour contrasts with the surroundings they are especially conspicuous. Rings of this kind are shown in fig. 443 formed by the Ascomycete *Spathularia flavida*. The subterranean mycelium of this Fungus exercises no injurious influence on plants in the immediate neighbourhood—at any rate, the mosses, grasses, and weeds which compose the carpet of the meadow round about show no sign of weakness, but are equally fresh and luxuriant within and without the rings. But it is not so in meadows where *Agarics* of the genus *Marasmius* and others have settled. The meadow-plants whose roots and root-stocks have been penetrated by their mycelia die off, and the places can be easily recognized by the withering and discoloration of their green aerial parts. On first looking at these spots one might easily suppose that the foundations of old circular walls were lying close under the turf which had

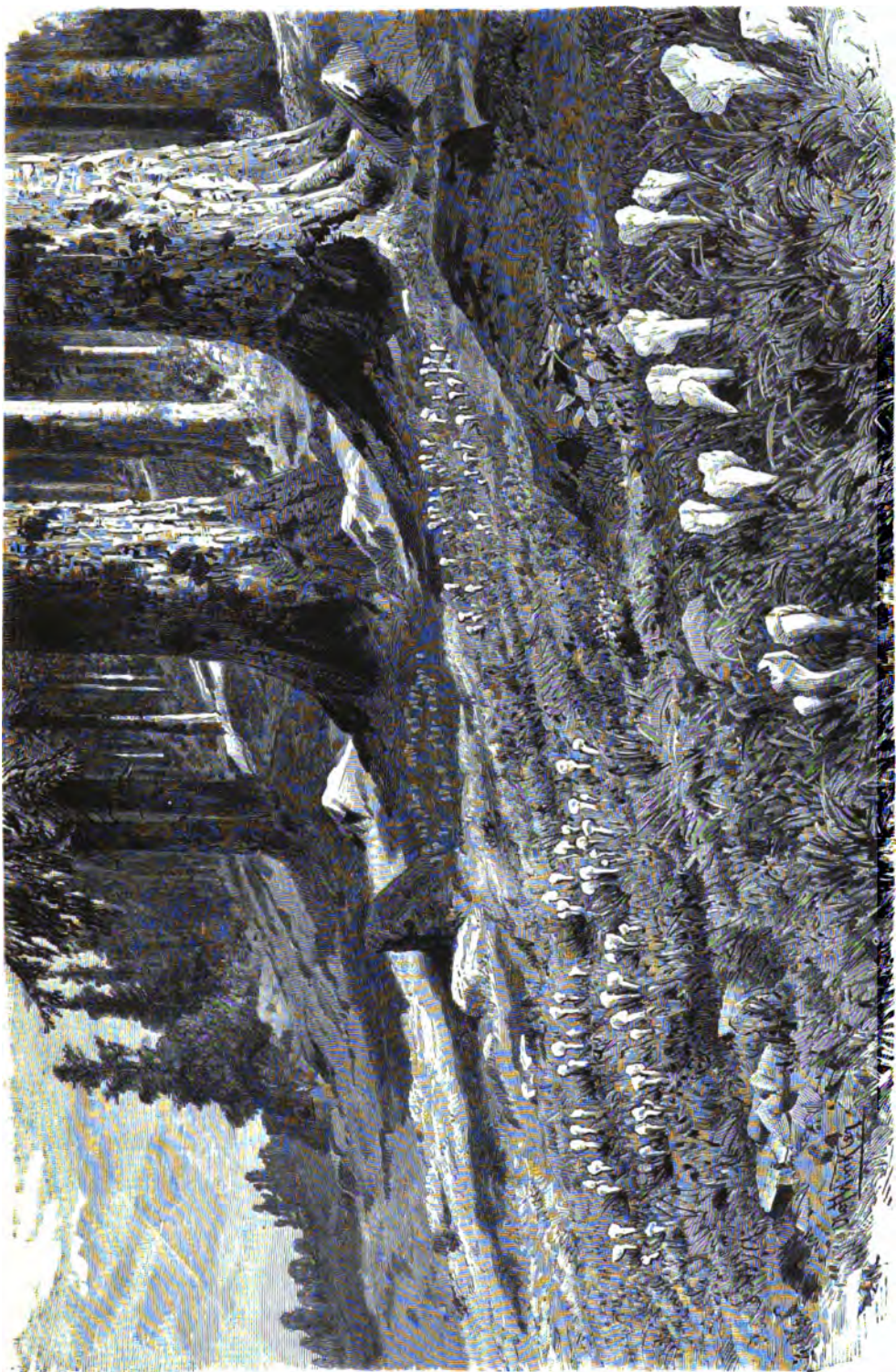


Fig. 443.—Fairy Rings in a meadow near Tyrol, formed by the ascomycetous fungus *Spathularia flavida*.

in consequence dried up above the stones; that this is not so may be readily proved by digging, and this shows us at the same time that the humus and roots in these places are quite riddled and wrapped round by the mycelium of the Fungi named. The brown and grey ring- and crescent-shaped stripes show up most clearly on meadows because a parallel stripe of a specially vivid green is usually seen close to them. The reason of this is that, after two years, new plants develop in all those places which were formerly occupied by the mycelium, and have been abandoned by it in its centrifugal growth. Strangely enough, these plants are not the same species which were killed there in the previous year, but are herbs and grasses which find a suitable nourishing soil in the places which have lain waste for 1-2 years. The roots and root-stocks of the plants killed by the mycelium have meanwhile decomposed, together with the remains of the mycelium and the receptacles of the Fungi. The soil is thus manured, and plants which usually settle on fallow ground grow there in abundance. They raise luxuriant stems and leaves, and thus is produced on the inner side of each bare stripe a parallel one of a bright green colour.

This phenomenon has long been noticed by country people, particularly in regions where pastures are an important feature. It is associated with the influence of ghosts, witches, and elves; hence the name of fairy rings. In Upper Austria these bare dry spots are regarded as the rendezvous of the witches, and Walpurgis Night (1st May) is supposed to be the time when they are produced. In the Tyrol and other primitive countries the most varied superstitions are held to account for these curious stripes and patches.

Fairy rings are sometimes formed by plants with underground rhizomes and runners, although not so frequently as by the subterranean mycelia of the Fungi named. Some Composites (for example *Petasites niveus* and *P. officinalis*, *Arnica Chamissonis*, *Achillea Millefolium*), Labiates (*Betonica grandiflora*, *Mentha alpigena*), Irises (*Iris arenaria* and *I. Pallasii*), Grasses, Sedges, and Rushes (*Hierochloa borealis*, *Sesleria cœrulea*, *Carex Schreberi*, *Juncus trifidus*), under suitable conditions of soil form ring-shaped and garland-like colonies independently of Fungi. The mode of growth in these plants is like that of the Dry-rot. Young plants grow up with closely crowded shoots; these then spread out on all sides, and the connecting links die off simultaneously. In this way the original settlement is left a bare patch with dried remains surrounded by a circle of distinct and vigorous offshoots. Though shoots are very numerous they still stand close together even after they have severed connection, and if their annual growth is but slight it is some time before an actual ring is formed. It is in this case, however, the more striking, so that even a casual passer-by cannot fail to notice it. This happens principally in the above-named Grass-like plants, and among them especially in *Sesleria cœrulea*, which has attained a certain celebrity in Sweden as the ring-forming plant. It is there popularly termed *elf dansar*, and legend has it that the elves are especially fond of holding their nightly dances on places where rings of this Grass have been formed.

Of course good rings are only produced by the plants named if the foremost buds produced by the subterranean internodes, i.e. those which form the terminations of the radiating stock or rhizome, undergo further development, while the intervening ones perish. This may not be the case under certain conditions, particularly if the growth of the terminal buds is retarded or stopped. For this reason fairy rings are formed much less frequently on stony, uneven ground than on flat homogeneous soils; and the best lands for this kind of fairy rings are pastures stretching over a mountain plateau, or the even floor of a valley.

If specimens of the plants here described are planted on smooth ground, in good soil in a garden, in places where there is no obstacle to their spreading, they will form the rings and wreaths in question within a few years. But in spite of this, very few people are ever able to witness this interesting spectacle in gardens, because gardeners will not leave the rings alone, regarding the bare patch in the centre as unsightly and that the existence of a ring is a slur upon their craftsmanship. I remember noticing this many years ago in the Botanic Gardens at Innsbruck. The perennial plants were cultivated in certain beds close together, and to each species was allotted a limited amount of space. When the spring came round the gardener dug up the periphery of the circle, and planted it in the centre, to catch the escaping plants, as he put it. In the spots where *Mentha alpigena* had stood the previous year only a few withered stumps were to be seen, and not a single living shoot could be found. But shoots with their tops above the ground could be seen in a circle in the neighbouring beds, and also in the paths between the beds all round the space set apart for this species of Mint. These shoots were ruthlessly dug up and planted again in the forsaken spot. Every year or every second year this capturing of the fugitives was repeated, not only in the case of the Mint, but in many other instances, as, for example, *Achillea asplenifolia* and *A. tomentosa*, *Betonica grandiflora*, and *Lysimachia thyrsiflora*.

Amongst aerial-sprouting plants which form rings and wreaths may be numbered the majority of Moulds, Lichens, and Mosses. The Mould, *Penicillium glaucum*, which settles on the fruit rind of oranges, apples, and pears, at first makes its appearance as a mere point, but later as a circular spot, and finally as a distinct ring surrounding a brown and rotten centre.

The most striking of the ring-forming Lichens are those which stand out from their substratum on account of their colour. Most noticeable in this respect are the white *Parmelia conspersa*, which contrasts with the dark slate rock, and the saffron-yellow species *Amphiloma callopisma* and *Gasparrinia elegans*. The gelatinous Lichens, dark olive-green normally, but black when dried, especially *Collema multifidum* and *C. pulposum*, often form such regular wreaths on a light background of limestone that they look as if they had been drawn with compasses, and the tiny yellowish-red *Physcia cirrochroa* has a particularly elegant appearance when it has radiated out from the hundreds of spots where it established itself on the flat surfaces of a steep calcareous rock. One might almost think that the small orange wreaths had been painted in with a brush. They also remind one of the fleecy

clouds in the evening sky, whose edges are reddened with the rays of the setting sun; and if I am not mistaken, this Lichen has obtained its name on account of this resemblance.

The chief Liverworts and Mosses which form rings and wreaths when they grow on the flat surfaces of steep rock-faces and on the bark of old tree-trunks, are *Frullania dilatata*, *Radula complanata*, *Amblystegium serpens*, *Anomodon viticulosus*, and *Hypnum Halleri*. When they first settle they are scarcely noticeable on account of their minuteness, but they spread very rapidly, their firmly adherent stems forking and radiating out in all directions, the whole plant at a little distance now forming a greenish-yellow spot of circular outline. While growth proceeds in this way round the periphery of the Moss-plant, covering the rock or bark like a carpet by the multiplication of its outer forked branches, the older parts near the original place of settlement become dry, disintegrate, and are blown away like dust by the wind, the naked rock or bare bark thus again coming into view. In this way 5, 10, or 20 new Moss-plants are derived from the original one, and stand in a circle round the bare centre. This circle widens from year to year, until at last it is interrupted by gaps, and then 20 or more specimens of the Moss are seen adhering to the substratum arranged in a circle more than a span from the original settling place.

In order that the ring or wreath arrangement of the offshoots above described should obtain, it is necessary that the original plant should dry up and decompose, and that the shoots which radiate from it should also die off behind in proportion as their growing points travel away from the centre of the settlement, and, finally, that no new ring-forming species should establish itself, or spread on the dead centre for a considerable time. These conditions are only comparatively rarely fulfilled, and this is the reason that ring and wreath formations are relatively so scarce.

It happens much more frequently that the plant forming the starting-point of a colony, after it has sent out creeping threads of cells, runners, shoots, and the like in all directions, does not itself perish, but remains living and active in the centre of its separated shoots, even sending out new shoots year after year. In the same way the separated shoots repeat the parent-method of growth, i.e. they send out shoots in all directions like the mother-plant, though perhaps less regularly, and thus of necessity some of the young shoots come back to the bare centre and settle down where the mother-plant originally stood. The following phenomenon may also be observed: A plant gives off annually a pair of horizontal shoots on one side only, let us say on the south; their buds in the course of time become independent plants, and each again sends out a few horizontal shoots towards the south. In a few years' time these offshoots give rise to 20-30 plants, which are more or less distant from the starting-point, according to the length of the shoots. In all these cases the offshoots are not arranged in a ring or wreath round an empty centre, but in lines or clusters.

Like the ring- and wreath-forming colonies, the offshoots, forming lines and clusters, may be underground or aerial. The receptacles of many Fungi emerge in a

clearly lineal arrangement from the mycelial threads running below the surface of the ground and in dead, rotten tree-trunks. Some Mosses form colonies in very regular lines from their rhizoids and horizontal underground protonemas. The most conspicuous, however, is the line formation produced by roots which run horizontally below the soil. The Aspen (*Populus tremula*), the Sea Buckthorn (*Hippophae rhamnoides*), *Lycium barbarum*, the Raspberry (*Rubus Idæus*), the Dwarf Elder (*Sambucus Ebulus*), *Asclepias Cornuti*, various species of *Linaria* and *Euphorbia*, and numerous other plants (cf. p. 27) produce special horizontal underground roots, which give off buds towards the upper side. The shoots arising from these buds form separate independent plants after the root which formed them has died away. Obviously the plants follow the direction of the roots, and are arranged in rows. Even for years afterwards the line-like arrangement of the individuals in such colonies can still be recognized. When the bud-forming roots are of considerable length, the terminal offshoots are sometimes situated at some distance from the mother-plant. I saw single offshoots from the root of an Aspen push up through the ground 30 paces from the woody parent stem. Stems of *Asclepias Cornuti* spring up from the thick horizontal roots deep under the ground, at intervals of about 40 cm., and in them also can the linear arrangement be sometimes very clearly seen. When the individual offshoots in their turn give rise to horizontal roots, the line-formation is lost sight of more and more, and a scattered group spread over a wide area is the result. Sometimes the older portions of the colony die off completely, and as the individuals in one direction disappear, those in the other grow more luxuriantly. One might almost suppose the whole group to have taken a few steps forwards. This phenomenon can be seen particularly well in Raspberry bushes. On suitable soil a group of Raspberries will move about 2 paces every year, and therefore, after 10 years, they may have moved about 20 paces. If Raspberry bushes are planted near an inclosed piece of ground along a fence or hedge, it may happen that ten years later not a single one can be seen in the original place, while on the other side of the fence, in the neighbouring piece of ground, quite an assemblage of Raspberry plants has come into existence.

The clustered or linear colonies which spring from underground tubers have the following very simple history. After a tuber has been fully formed on the underground shoot of a plant the slender bridge-like connections which have hitherto served for the conduction of food break down by the decay and decomposition of their tissues. The new tubers thus separated from the mother-plant send out stems from their buds, after the necessary period of rest these push up above the ground and also give rise to new subterranean shoots with tuberous swellings. These fresh tubers, after they have become disconnected, again form the starting-points for tuber-forming plants. This goes on until after a few years the soil all round the place where the first tuber had been is crowded with hundreds of separate tubers, and corresponding to these above the ground is a group of hundreds of separate leafy stalks. It depends of course on the number and length of the underground tuber-forming shoots whether the group is crowded or scattered. In the Artichoke

(*Helianthus tuberosus*) the tuber-forming shoots are short; the colony is therefore crowded, and only spreads slowly over a larger area. The Alpine Enchanter's Nightshade (*Circæa alpina*; see fig. 444³) forms elongated tubers at the end of shoots 6 cm. in length, about 5 of them round the mother-plant, whilst each of the new plants arising from these tubers repeats this formation in the same colony. Since 6 cm. is a considerable length compared with the size of the Enchanter's Nightshade, the group is scattered and in a few years extends over a considerable area. The tuber formation of *Thladiantha dubia*, a gourd-like plant growing in

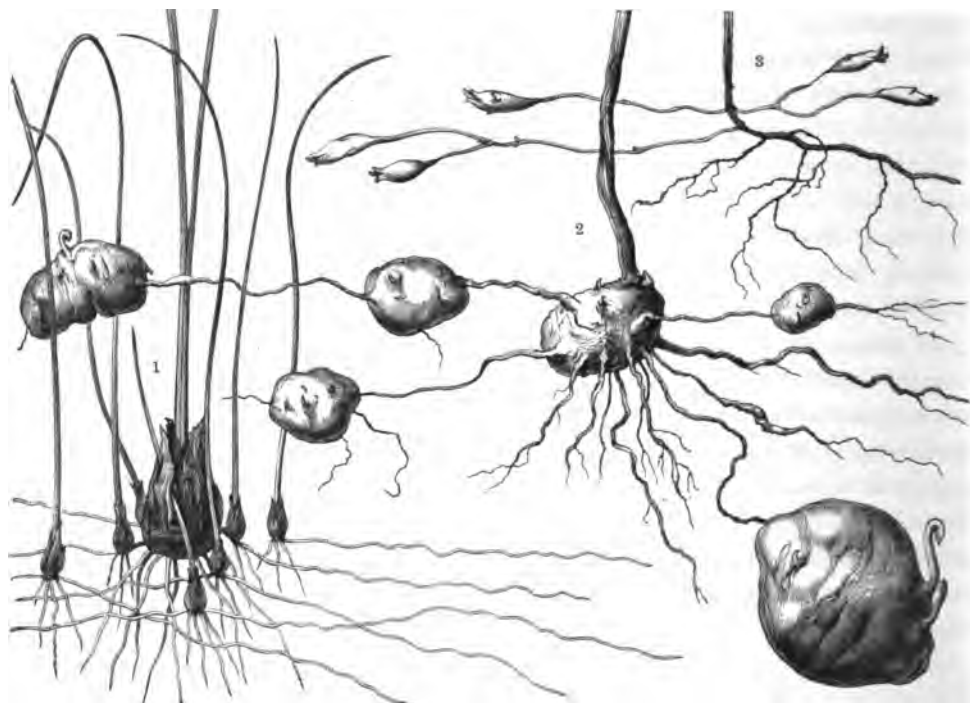


Fig. 444.—Plants with tubers and bulbe whose mode of growth leads to the formation of colonies arranged in lines and clusters. 1 *Muscari racemosum*. 2 *Thladiantha dubia*. 3 *Circæa alpina*.

Eastern Asia, is especially luxuriant; its shoot-formation is shown in fig. 444². In this plant a whole series of tubers which are chained together by thin threads 4–8 cm. long is formed on each shoot. Usually they form series of 5–10, and such a chain is about 50 cm. long. As a new plant grows from each tuber and again produces chains of underground tubers, the *Thladiantha* in a few years may occupy an area of 10 sq. metres, and will form a cluster which is both crowded and rapidly increasing in circumference. A further excellent example of the same thing is *Glauz maritima* which often spreads in the most diagrammatic manner in bare sandy places near the sea-shore.

Many tuber-forming plants producing clustered colonies inhabit marshes, especially such as are liable to great alteration in the level of the water and are exposed in years of drought to the danger of temporarily drying up. Many Pond-

weeds (*Potamogeton*), e.g. *Potamogeton pectinatus*, form a large number of small tubercles on their shoots which creep horizontally through the mud; *Scirpus tuberosus*, like the Alpine Enchanter's Nightshade, forms underground shoots 10–15 cm. in length, each terminating in a tuber as large as a chestnut, and since the plants to which these tubers give rise themselves repeat this formation of offshoots, the diameter of the clustered colony increases about 20–30 cm. every year. The Arrow-head (*Sagittaria sagittifolia*) also develops peculiar tubers. In the autumn, offshoots whose scale-leaves terminate in a sharp point not unlike those of the Couch-grass spring from the knotty stems hidden in the mud. The leaf which envelops the swollen end of the offshoot has a stiff point and plays the part of an earth-borer or rather of a mud-borer, since it makes a path for the offshoot which may elongate as much as 25 cm. The swollen end of the offshoot, which is about the size of a hazel-nut, bears a small bud with greenish, closely-folded leaves, and this, together with its tuberous support, remains alive during the winter, while the plant to which the offshoots owed their origin perishes. In the following spring each of the small buds grows up into a new plant at the expense of the reserve-materials stored in the tuber, and now instead of the old dead plant we have a small group of young independent plants rising from the mud.

The colonies of offshoots arranged in lines and clusters, which are developed from underground rhizomes and shoots, elongate horizontally, and form buds laterally and at their growing point, and in the same proportion as they fork and divide in front they die off behind, so that the individual sprouts become separated. To this category belong several species of *Dentaria*, *Anemone*, Couch-grass (*Agropyrum*), Mint (*Mentha*), Yarrow (*Achillea*), Willow-herb (*Epilobium*), Butterbur (*Petasites*), and the Woodruff (*Asperula odorata*). The length of the underground shoots which form the buds in these plants is very varied, as will be clearly seen from the table we insert here.

Centimetres.		Centimetres.		Centimetres.	
<i>Anemone ranunculoides</i> . . .	5-10	<i>Epimedium alpinum</i> . . .	15-20	<i>Hierochloa borealis</i> . . .	35-45
<i>Monarda fistulosa</i> . . .		<i>Silene alpestris</i> . . .		<i>Urtica dioica</i> . . .	
<i>Melissa officinalis</i> . . .		<i>Mentha viridis</i> . . .		<i>Carex pilosa</i> . . .	
<i>Origanum vulgare</i> . . .		<i>Asperula odorata</i> . . .	20-25	<i>Glauz maritima</i> . . .	45-55
<i>Achillea Millefolium</i> . . .		<i>Mentha piperita</i> . . .		<i>Arnica Chamissonis</i> . . .	
<i>Equisetum arvense</i> . . .	10-15	<i>Rubia tinctorum</i> . . .		25-30	<i>Daphne Philippi</i> . . .
<i>Asperula taurina</i> . . .		<i>Senecio Fuchsii</i> . . .	<i>Senecio fluviatilis</i> . . .		
<i>Oxalis corniculata</i> . . .		<i>Mercurialis perennis</i> . . .	<i>Tussilago Farfara</i> . . .	60-75	
<i>Betonica grandiflora</i> . . .		<i>Mentha crispata</i> . . .	<i>Solidago canadensis</i> . . .		
<i>Tanacetum Balsamita</i> . . .		15-20	<i>Agropyrum repens</i> . . .	30-35	<i>Petasites niveus</i> . . .
<i>Aster salignus</i> . . .	<i>Ægopodium Podagraria</i> . . .		<i>Mentha alpigena</i> . . .		
<i>Dentaria glandulosa</i> . . .	<i>Convolvulus arvensis</i> . . .		<i>Nardosmia fragrans</i> . . .		85-100
<i>Carex arenaria</i> . . .	<i>Saponaria officinalis</i> . . .		<i>Epilobium angustifolium</i> . . .		
<i>Juncus arcticus</i> . . .		<i>Potentilla bifurca</i> . . .	35-45	<i>Petasites officinalis</i> . . .	100-150

These numbers do not represent the lengths of single internodes, but those of the whole annual underground shoots which may consist of many internodes. For example, the year's underground shoot of the Umbellifer *Ægopodium Podagraria* has 8 internodes, of which the proximal one is the longest and the distal the shortest.

The rapidity of the extension and the dimension of the colonies which are produced from rhizomes and runners depends upon the length of the annual shoot, and upon whether or not the soil is favourable to the spreading of the offshoots, just as it does in the linear or clustered colonies arising from underground roots and tubers. In wood-clearings and on the banks of rivers many of these plants develop in a surprisingly short time, as, for example, *Calamagrostis Epigeios*, *Epilobium angustifolium*, the North American Golden Rod and Rudbeckias (*Solidago Canadensis* and *Rudbeckia laciniata*), and these also have the property of suppressing and destroying all other vegetation in places where they have taken possession. This fact is turned to practical account by farmers who use certain Grasses which form linear and clustered offshoots to bind together loose soil, especially river sand. But there are also plants in this category which are veritable plagues to the farmer, the establishment and propagation of which he opposes by every means in his power. Examples of these dreaded plants, which, when they establish themselves in the fields and garden-beds, hinder the development of other plants, are furnished by the Gout-weed (*Ægopodium Podagraria*), the Stinging Nettle (*Urtica dioica*), and the Fuller's Thistle (*Cirsium arvense*). Wherever these have settled on cultivated ground and penetrated the soil with their offshoots there is nothing for it but to dig up the whole ground and to carefully remove all the shoots. Unfortunately even this laborious task is not always rewarded with the desired result, for in spite of the utmost care it may happen that small fragments remain, and these form the nucleus of a new colony of weeds. In a short time a new group appears above the soil which has been cleared with so much care, and a fresh digging and still more careful clearing of the ground is necessary. These clustered colonies have a characteristic appearance when foliage-leaves spring from their underground stem-structures, the large blades being borne on almost equally long erect stalks, as is the case, for example, in the Butterbur (*Petasites officinalis*) and numerous tropical Aroids. Wide tracts are then to be seen covered exclusively with their large luxuriant foliage-leaves, all other vegetation being suppressed. The formation of offshoots and the production of clustered colonies also occurs to a remarkable extent in the common Reed (*Phragmites communis*). Once settled on suitable soil it will cover the widest areas in uninterrupted and unhindered march, suppressing and destroying all other plants. On the lower Danube there are many lowlands so thickly set with Reeds that in several hours' journey only a few small inconspicuous plants will be seen beside the Reed haulms. This Reed is also interesting from the fact that its offshoots can arise just as well under water as under the ground, and it may serve, in some respects, as the type of a group of plants which, by reason of their amphibious nature, play an important part in the transformation of submerged into dry land.

On the other hand, the variety of the protonemal threads, runners, shoots, and creeping stems which spread above-ground from the offshoots of these colonies is almost inexhaustible. And this is readily intelligible. The processes which are connected with their formation are much more varied in plant-members which grow

in the light and in open air than in those which develop under the water or the soil, or, perhaps we should rather say, that above the ground the greater fluctuations in light, moisture, and temperature bring about corresponding modifications in the vital processes. Moreover, the substratum presents every imaginable gradation from shifting quicksand to heavy clay, from steep rock-faces in one place to the bark of old tree-trunks in another, all these having by no means the same effect on the formation of offshoots. One of the most noteworthy processes occurring above the ground leading to the formation of clustered offshoots is that exhibited by Moss-protonemas. By protonema is meant a web of threads which spreads sometimes as a loose, open network, sometimes as a thick felt, over rock, clay, sand, earth, humus, bark, and decayed wood, the individual cells becoming the starting-points

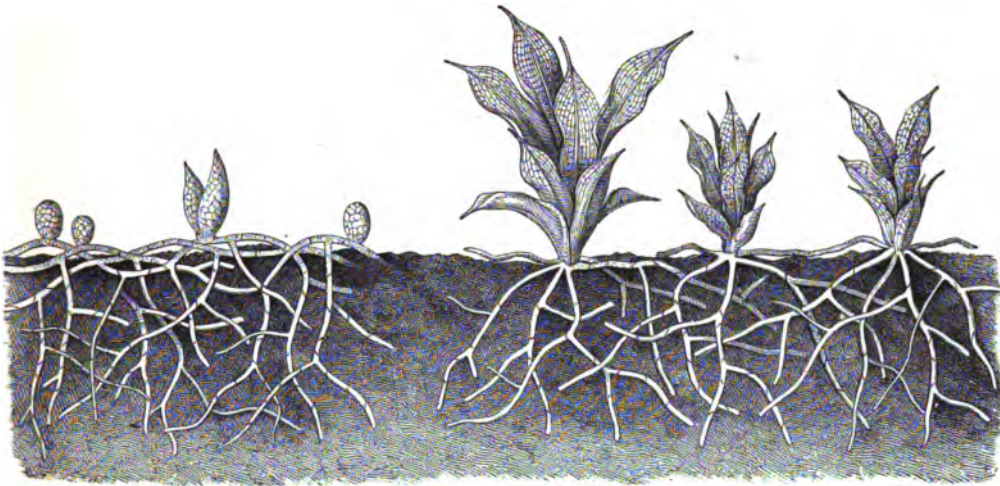


Fig. 445.—A section through soil permeated by the protonemal threads of the Moss *Pottia intermedia*. (Magnified.)

of new Moss stems. This protonema may be compared to a web of Strawberry runners which has spread over the ground in a wood-clearing. Just as small plants spring up from the thread-like runners in this case, so Moss-plants are produced from the protonemal threads, and by the dying away of the latter become isolated. In many Mosses the end comes with the formation of this clustered arrangement, as, for example, in the tiny Mosses classed together as Pottiaceæ, of which one species, *Pottia intermedia*, is shown in fig. 445. This plant has the following remarkable history. During the period when most other plants are engaged in active nutrition and reproduction it remains with its rhizoids and part of the protonemal threads imbedded in the ground. Numerous scattered spores also remain resting in the ground until at length the time for aërial development arrives. Strangely enough, however, this is not until late in the autumn, when the leafy trees have discarded their foliage and autumnal mists drift through their bare branches. Then on the surface of the bare, cold, damp earth appear green threads which at first look like algal filaments, and on these small buds are formed (see fig. 445). In the course of a few weeks Moss-plants grow up from these buds

which become independent by the gradual withering and decomposition of the connecting pieces of thread. They form spherical spore-capsules, and with the scattering of the spores they wither and die. These plants are only a few millimetres high, but they are clustered together in such thousands that they form a velvety carpet over the soil, their emerald-green colour being the more striking as the last remains of the neighbouring vegetation have assumed the dull hues of decay. The Luminous Moss (*Schistostega osmundacea*) growing in the holes and clefts of slate mountains (already described in vol. i.), the protonema of which is depicted in Plate I., also forms loose colonies of separate Moss-plants from the green threads which creep over the clayey soil in the hollows. These plants die off after they have ripened their fruits. Of course the development is in this case not so rapid and does not occur in the late autumn as in *Pottia intermedia*.

A peculiar formation of offshoots may be noticed in epiphytes which climb over the bark of old trees and possess only short ribbon-like roots adhering to the damp bark, but none which grow down into the ground. Their stems and leaves invest the substratum like a carpet, as, for example, in several tropical Aroids of the genus *Pothos*, and in *Marcgravia*. The growing stem forks, and later on by the dying away of older portions behind the fork the two branches are separated and isolated. Each in its further growth may go a different way, one climbing up this and the other up that branch of the tree-trunk which serves as support; and, since this process is repeated, several independent plants of *Marcgravia* and *Pothos* may be found on the crown of the tree, all of which are to be regarded as natural offshoots. The same thing occurs in numerous Ferns, which grow on the bark of trees and in the humus-filled clefts of rocks, and in all those plants whose creeping aerial stems grow and branch at one end while they die off to a corresponding extent behind, as in many creeping species of clover, for example. As the annual increase in the stem of these plants is but small, the separated individuals move very slowly from one another, and several years elapse before the offshoots have formed a group which extends over an area of a square half-metre.

The result is obtained comparatively much quicker when the offshoots are formed by runners and shoots. In one section of these plants, of which the *Saxifraga flagellaris* (fig. 446), a plant widely spread through the Arctic region and in the high mountain districts of the Himalayas, Altai, and Caucasus, may be taken as a type, only a single bud is developed at the end of a slender thread-like shoot. This takes root where it touches the ground, and grows up into a rosette. Not until the nourishment of the rosette by the rootlets which have been sent into the ground is assured does the long thread, terminated by the bud, die off, the connection with the mother-plant being thus severed, whilst the rosette now forms an independent plant. Since the shoots are usually numerous and radiate outwards the mother-plant in course of time becomes surrounded with an actual garland of rosette-shaped offshoots, and in a few years a fairly large area is covered with hundreds of larger and smaller rosettes, which, however, no longer show the circular arrangement, because the shoots of neighbouring rosettes often cross, and consequently the circles intersect.

Everyone knows the long runners of the Strawberry plant (*Fragaria vesca*). Here buds arise at the intermediate nodes as well as at the tip of the runner, and these develop into new plants after the thread-like connecting portions have perished. Suppose a Strawberry stock sends out three runners during the summer; each takes root at 5 nodes, and from each node a bud, i.e. an offshoot, develops, so that the following year the mother-stock is surrounded by fifteen daughter-plants. It should be noted that the length of the internodes in each runner is unequal. For example,



Fig. 446.—Formation of a clustered colony by means of aerial runners in *Saxifraga flagellaris*.

in one which had extended over the ground in the shade of the wood, the first internode was 37, the second 34, the third 31, the fourth 30, and the fifth and last 22 cm.; thus the offshoots were the closer together the greater their distance from the mother-plant. Next summer fifteen new offshoots were again formed from each of the original fifteen, arranged in exactly the same way, and in the forest-glade, where two years previously there had been only a single Strawberry plant occupying a space of 50 sq. cm., there would now be 200 plants distributed over a space of about 3600 sq. cm.

The lesser Spearwort (*Ranunculus reptans*), the Ground Ivy (*Glechoma hederacea*), and the creeping Cinquefoil (*Potentilla reptans*) display quite as

considerable an increase and distribution as Strawberries. The accompanying table gives the length of runners and shoots of some well-known species in which the formation and rapid distribution of offshoots is particularly noticeable on suitable substrata.

	Centimetres.		Centimetres.		Centimetres.
<i>Saxifraga aizoon</i>	4	<i>Lycopodium annotinum</i> . .	30-40	<i>Vinca herbacea</i>	70
„ <i>cuneifolia</i>	6	<i>Saxifraga sarmentosa</i> . .	40	<i>Fragaria Indica</i>	85
„ <i>Geum</i>	8	<i>Ranunculus Flammula</i> . .	50	<i>Potentilla anserina</i>	110
„ <i>flagellaris</i>	10	<i>Geum reptans</i>		<i>Glechoma hederacea</i>	126
<i>Sempervivum stenopetalum</i> .	12	<i>Glyceria fluitans</i>		<i>Potentilla reptans</i>	130
<i>Viola odorata</i>	13	<i>Lithospermum purpureo-</i>		<i>Rubus saxatilis</i>	140
<i>Arabis procurrens</i>	16	<i>cæruleum</i>	56	<i>Fragaria vesca</i>	150
<i>Androsace sarmentosa</i> . . .	18	<i>Ranunculus reptans</i>	60	<i>Vinca major</i>	200
<i>Ajuga reptans</i>	20	<i>Tiarella cordifolia</i>	65	<i>Rubus Radula</i>	300
<i>Hieracium flagellare</i> . . .	30	<i>Vinca Libanotica</i>	66	„ <i>bifrons</i>	650

In those cases in which plants change their position by the development of offshoots in any direction, whilst they die off in the opposite one, progress is always restricted. The offshoots penetrate only by slow degrees in the surrounding soil, and many years elapse before a space of 100 metres is traversed in this way. The change of position is much more rapid when the offshoots become detached from their place of origin and are carried to a new spot by special mechanisms of transit, by currents of water, the wind, or finally by the help of men or animals. In this way it may happen that single detached cells, cell-groups, buds, and shoots may be carried vastly further than 100 metres in a few minutes, through long valleys, over steep precipices, or even over high mountain ridges. This rapid distribution is not indeed so certain in its result as the slower mode of progression. It may easily happen that the wind or water current lands the detached offshoot on some spot where further development is impossible, where it must inevitably perish. Apparently, however, this disadvantage is compensated for by the immense quantity of such detached offshoots. Again, there are plants which form two kinds of offshoots, those which propagate slowly but surely, which are few in number, and others, developed in large numbers, which are distributed rapidly but less certainly.

Only a very small proportion of plants develop offshoots which after they become detached reach a new locality spontaneously, by means of special organs of motility. This class of brood-body is always aquatic and of very small size, and its development can only be followed under the microscope. The best-known examples are Fungi, belonging to the Saprolegniaceæ and Chytridiaceæ, the dark green *Vaucherias*, and other species of Algæ. The Saprolegnias are saprophytes growing in and on the bodies of animals which have died in the water—not only fish, crustaceans, and insect larvæ, but also birds. They form delicate, thread-like, tubular hyphæ, which ramify repeatedly, and part of which penetrate into the corpse like a root-plexus, while the rest rise up above the body in the form of white or grey felt, which floats in the water. Single tubular erect hyphæ assume a knob or club-shaped form, and their protoplasm divides up into numerous portions. Ultimately the club-shaped tube opens at the apex, and the little proto-

plasmic bodies (swarmspores) escape (*cf.* fig. 192, p. 17). What happens next differs according to the species. In the genus *Saprolegnia* the individual swarmspores have two cilia, by means of which they immediately swim away (see figs. 192⁶ and 192⁷); in *Achlya*, on the other hand, the swarmspores group themselves into a round ball in front of the opening of the tube as they escape (*cf.* fig. 192^{1, 2, 3, 4}), and at first possess no cilia. They surround themselves there with a delicate capsule, which apparently consists of cellulose, but they do not remain long in this condition. A few hours after, they leave the capsule and assume a bean-shaped form, being now provided with cilia which enable them to swim about in the water. They only swim about for a comparatively short time. When they have settled on some spot they lose their cilia, surround themselves with a cell-wall, and become the starting-point of a new plant; therefore they must certainly be regarded as offshoots. The Chytridiaceæ have a similar offshoot formation. These too are devoid of chlorophyll, but they are true parasites, not saprophytes like the Saprolegniaceæ. They prefer green water-plants for their hosts, penetrating into their cells, killing and destroying the protoplasm, and then develop thick tubes which project beyond the host-plant, and in which the protoplasm becomes divided up into numerous spherical portions. The tubes open at their apex sometimes by the raising of an actual lid (see fig. 192⁵), sometimes by the dissolution of a limited portion of the cell-wall, so that a hole results from which the isolated protoplasts are expelled. On its escape each of these offshoots is spherical or egg-shaped in form, and possesses a single long cilium. This cilium serves as a swimming organ which in many species actually causes a hopping and springing movement. In order to avoid repetition, we may refer to the description of the swarmspore-formation given at vol. i. p. 29, in the case of the *Vaucherias* and *Sphærellas*.

On the whole, as we have already stated, the formation of offshoots which swim about independently in the water and seek out new spots suitable for settlement is restricted to a very small section of water-plants. Offshoots which, after their detachment from their place of origin, are carried passively by water currents without exercising any directive influence, and are stranded at some distant spot, are of much more frequent occurrence. Of these water-plants we might mention in the first place the filamentous green Algæ which cover with slimy masses the surface of slowly moving water or stones at the bottom of rapid streams. In many of these plants several times during the year do the dividing membranes between the individual cells break down into mucilage so that the cells become free and are carried away by the flowing water. Each of these cells may again give rise to a new thread by repeated division. We cannot easily conceive a more simple method of propagation and distribution than this. The offshoot-formation in the Floridææ is hardly less simple. Whether the whole plant is composed of rows or of open networks of cells, four protoplasmic balls, the so-called tetraspores, are formed in various situations on the plant; these are liberated into the surrounding water and carried away by the current. They adhere to some firm spot under water and there grow up into new plants. In most instances the protoplasm of the cell in

which the offshoot formation occurs is divided into four, more rarely two or eight clumps are formed by the splitting and dividing of the protoplasm, and most rarely of all is the whole undivided protoplasm of a cell transformed into a single offshoot.

The small group of water-plants known as the Hydrodictyaceæ display a peculiar offshoot-formation. In the elegant Water-net (*Hydrodictyon utriculatum*, cf. p. 640), whose cylindrical cells form a closed net with hexagonal meshes, the cells each originate new plants as Water-nets in miniature. The protoplasm in one of

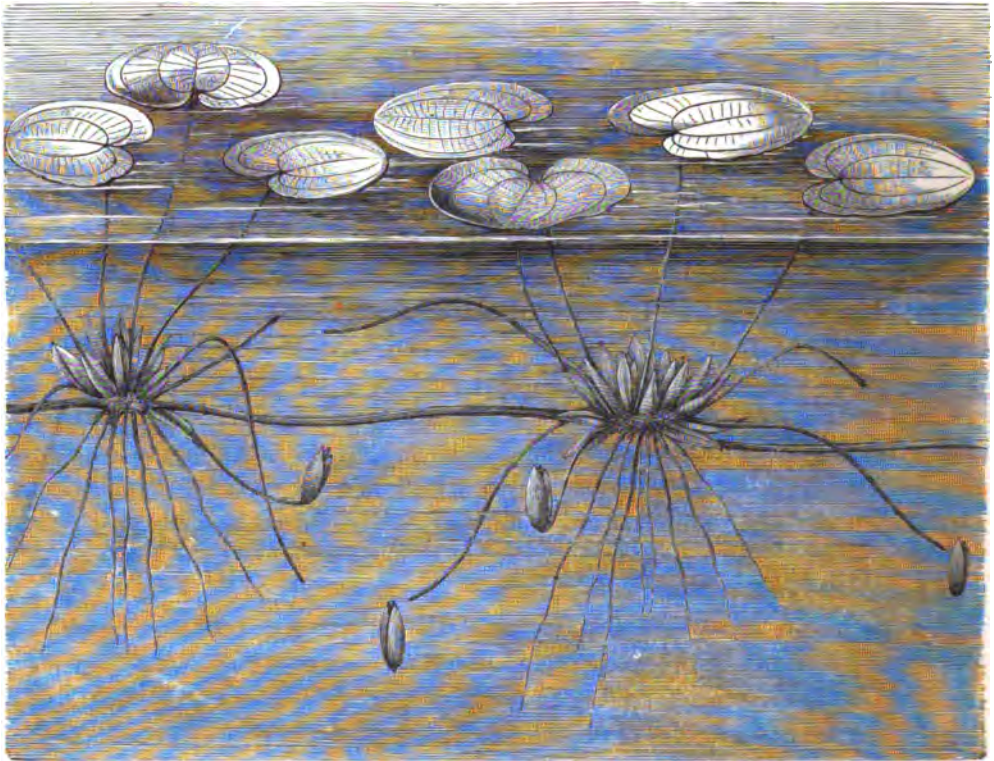


Fig. 447.—Frogbit (*Hydrocharis morsus-ranæ*). The winter buds in process of detachment from the ends of the submerged stolons.

the cells which is preparing for offshoot-formation divides into many thousand parts which quiver in a remarkable way and pass between one another, and are said to undergo the so-called swarming motion. This lasts about half an hour, then the swarming portions, whose rod-like form can be recognized in spite of their minuteness, come to rest, arrange themselves into nets with hexagonal meshes (see figs. 370^{3, 4, 5}, p. 640), and now each cell contains a tiny Water-net. The outer layer of the cell-wall in which this grouping has taken place is partially dissolved. The little net, at first still inclosed in a pellicle of protoplasm, slips out and swims freely in the water as an offshoot. In 3–4 weeks it has attained the size of the Water-net, from one of whose cells it emerged, and in each of its own cylindrical cells the same process may be repeated. A similar process is observed in the small water-plant

called *Pediastrum*, which is closely related to the Water-net, and of which one species is shown in figs. 370^{6,7,8}, p. 640.

The distribution of bud or sprout-like offshoots is seen especially in the Duckweeds, Alismaceæ, Potamogetons, Utriculariaceæ, Droseraceæ, and Primulaceæ. Most of the Duckweeds (e.g. *Lemna polyrrhiza* and *L. arrhiza*), which float during the summer on the surface of still water, towards the autumn form organs on their flattened stems which become detached from the summer plants, sink to the bottom

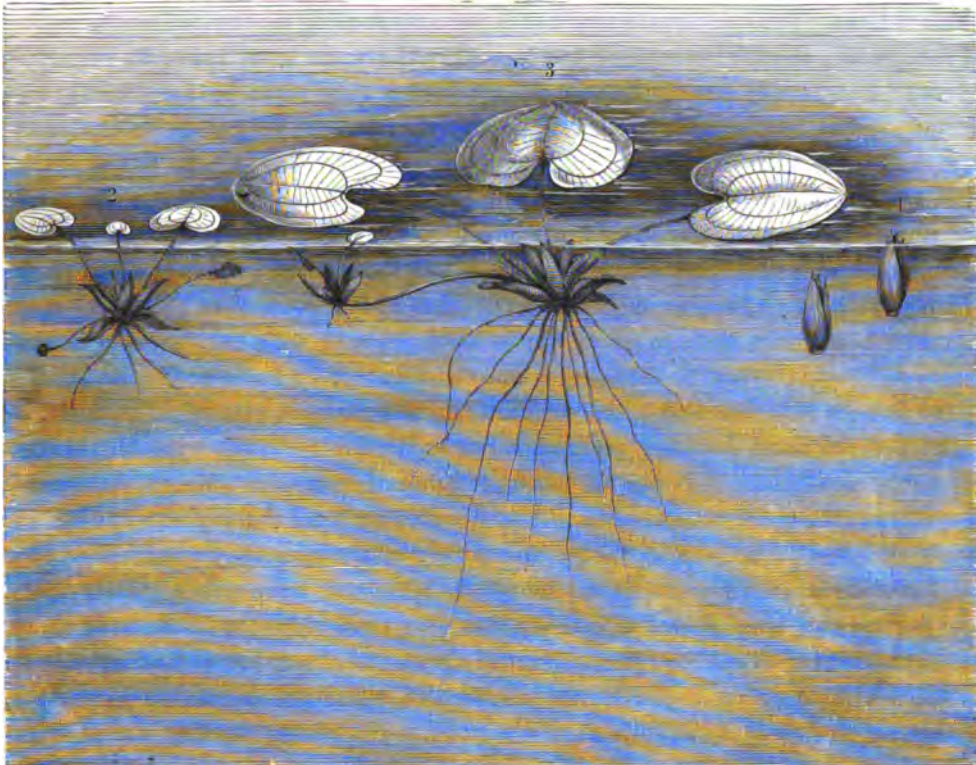


Fig. 448.—Frogbit (*Hydrocharis morsus-ranæ*). 1 Winter buds rising to the surface in spring. 2 Young floating plants which have developed from such buds. 3 Older floating plants.

of the lake, and stay there during the winter. Each of these organs is pocket-shaped, and in the hollow the next year's shoot is already laid down—of course, as a minute structure whose semicircular free end scarcely projects above the closely-adjointing edges of the pocket. These detached winter buds sink because their cells, even those of the epidermis, develop large starch grains which are crowded together, and literally fill up the lumens of the cells. There are no air-spaces like those which cause the summer-plants to float on the surface of the water; the stomata as yet are closed, and the whole body, hermetically sealed from the outer world, now has a specific gravity which causes it to sink down to the bottom of the water, where it is protected against the frost. There it remains in a resting condition during the winter. At the beginning of the warmer season the bud wakes from its winter

sleep, the starch-grains are used up in the building of the young stem, and the growing buds of these species of *Lemna* again rise to the surface of the water, because the cells which had served as storehouses for the starch become empty, and because air-spaces are formed in the new tissues.

The same change of position during the year is also observed in the offshoots of the Frogbit (*Hydrocharis Morsus-ranæ*), which is common in still waters through the whole of Europe and a great part of Asia. Although this plant is abundantly provided with roots, it never fixes itself by them to the slimy bottom of the pool in which it lives. Throughout the summer it remains floating on the surface, spreading its foliage like the Water-lilies on the top, while its roots hang below in the upper layers of water. Its propagation in the summer is very rapid by the formation of offshoots. These arise in the axils of foliage-leaves from the very short, erect, floating stem, and are rather long, resembling thick threads, which keep close to the surface of the water, and grow in a horizontal direction. Each shoot terminates in a bud, and this quickly opens, sending up green foliage to float on the water, and a bunch of roots below. In a very short time the plant thus formed resembles the parent which gave it origin, and is itself able to develop new shoots. Thus it comes about that in a few weeks the surface of the water is covered with innumerable floating plants of Frogbit, every 10–20 being connected together by horizontal strands. The pretty flowers now rise above the surface from the stronger plants. The flowering is, however, of short duration, and is seldom successful, i.e. fruits with fertile seeds are rarely produced. As soon as the blossoming is over and autumn approaches, new shoots ending in buds appear. They are shorter than those of the spring, and they sink lower on account of the greater weight of the buds they carry. The buds, too, have a rather different form. They are firm, and wrapped in closely-fitting scale-leaves, and they almost attain the size of a small date-seed. As soon as the bud is provided with the requisite amount of starch and other reserve food-substances, it becomes detached from its filamentous support, and sinks down (see fig. 447) till it rests on the mud at the bottom of the pond. The plants floating above, which gave rise to them, die off completely and decay. It is high time indeed to quit the field above, for the surface of the water is soon covered with a sheet of ice, which renders all vital activity impossible for months. When spring again arrives, and the ice vanishes from the pools and ponds, new life rises up from the mud below. The buds of the Frogbit which have passed the winter there become spongy, the cell-cavities fill with air, and the whole structure rises to the surface (see fig. 448¹). Arrived there the scale-leaves rapidly separate, green leaves expand their blades on the sunlit surface, roots hang down into the water, and before long, shoots are again developed as already described (fig. 448²). Obviously deviations of position and sometimes considerable changes of place are brought about by the sinking and rising of the buds in the water. It is observed, too, that the Frogbit is very variable in regard to its position, and that sometimes a place whose surface was one year covered with numberless plants will in the year following present no trace of them, while new colonies will have developed at a distance.

The Bladderworts (*Utricularia*), Aldrovandias (*Aldrovandia vesiculosa*, see vol. i. p. 151), and the Water Violet (*Hottonia palustris*), which desert the cold upper strata of water as winter sets in, and sink down to the relatively warm depths below, develop special wandering buds for this purpose; these are not enveloped in scale-leaves like those of the Frogbit; they are in reality merely much abbreviated shoots whose leaves are so crowded and folded so closely together, that the whole shoot looks like a rounded green ball. These balls at first remain connected to the piece of the floating stem which gave them origin. This attachment is lost towards the end of autumn, and the little buds sink down to the bottom of the pond and necessarily get distributed in various directions. Next summer, when the balls leave their winter quarters and are again carried to the upper strata of water, they expand into foliage-bearing plants. It has been already stated (vol. i. pp. 76 and 658) that the Water Soldier (*Stratiotes aloides*), which is closely-related to the Frogbit, undergoes similar changes during the year, and we need here only draw attention to the fact that it sinks down to its winter quarters at the bottom of the pond as an open rosette, and not in the form of buds, and rises again the ensuing spring when the weather is more favourable.

The Pondweeds *Potamogeton crispus*, *obtusifolius*, *pusillus*, and *trichoides* behave differently from the marsh and water plants hitherto described. Here, as autumn approaches, buds are developed which become detached from the old decaying stems (fig. 136, vol. i. p. 551), and sink down to the bottom of the pond; but in the following summer they remain sticking in the mud at the spot where they fell, and do not rise again to the surface. They send out roots and develop much-branched leafy stalks, and these rapidly grow up to the surface of the water. These Pondweeds, firmly rooted to the bottom of the pond, multiply not only by these free-swimming offshoots, but also by stolons which creep far and wide through the mud; but of course the plants are distributed to much greater distances by the sprouts or buds which are developed in the autumn on the upper internodes, and which then become detached and float in the water, than would be possible by the creeping stolons alone.

A very remarkable distribution of offshoots is to be observed in the marine *Cymodocea Antarctica*, which is very common on the coast of Australia, south of the Tropics. This plant has an erect stem, thickly covered with dull-green foliage-leaves, arranged in two rows. The lower leaves fall off prematurely, and the bare scarred stem then carries only a bunch of ribbon-shaped leaves at its summit. Towards the close of the winter the end of the stem above these leaves is seen to become peculiarly modified. Its internodes become much contracted, and at the lowest node is developed a scale-leaf with four lobes, which surrounds the leaves developed from the upper nodes, like a cup. Buds arise in the axils of one or two of these leaves, while the leaves themselves die and decay. The parenchyma of the four-lobed, cup-shaped scale-leaf also decays, and only its stiff veins remain, so that instead of the cup, there are now only comb-like scales. After this alteration has taken place, the tissue of the stem below the pectinate scales breaks across,

and the whole shoot-apex, separated from the lower part of the stem, which has long been in a leafless condition, is carried away by the currents of the water. How far and for how long the shoot is carried about depends upon the local condition of the sea-shore. Sooner or later its career of wanderer is arrested by the trailing comb-like scales assuming the rôle of anchors. As soon as the anchor is fast, some 2-4 roots develop from the lower internodes of the shoot; these pass between the teeth of the comb-like anchor, and grow down into the muddy substratum, thus fixing the offshoot. All this happens at the end of winter. During the following summer, the shoot, which is about 8 cm. long, and is anchored and rooted in the mud, again grows up into a stem about a metre high, and next winter its top again falls off just in the same way. It has already been mentioned (p. 457) that this strange sea-plant very rarely blossoms or fructifies—a circumstance which confirms the supposition that the boundless colonies of it round the coasts of Tasmania owe their origin to the offshoots distributed by the sea currents.

The distribution of offshots by sea-water is a much simpler affair in the Seawracks, *Ulvas*, and *Floridææ* than in these other water-plants. When the sea is stirred to its depths by violent storms and the spring-tide is higher than usual the retreating waves leave any quantity of fragments of these plants behind them. These have been torn by the raging water from the firmly-fastened ribbons, nets, and threads below, and are then carried away by the billows. The water drives them into clefts of the rocky coast or imbeds them in the sand and mud of the shore, and, wonderful to relate, not a few of them flourish again, granted of course that they are not speedily removed by subsequent tides and that the circumstances are otherwise favourable.

Much the same kind of thing happens on the banks of rivers and streams. A portion of the plant-fragments brought by floods and stranded on the mud of calm inlets undergoes decomposition. A larger portion remains fresh and living, sending out roots and vigorous shoots. In the bed of the Danube, in addition to the abundant creeping shoots of the Reeds (*Phragmites*) and various Sedges, Bulrushes (*Scirpus*, *Typha*), broken twigs of *Salix fragilis*, bits of roots of the Sea Buckthorn (*Hippophae rhamnoides*), fragments of the rhizomes of *Ænanthe Phelandrium* and *Acorus Calamus*, leafy twigs and stolons of various species of Pondweed, Water-Milfoil, and Water Ranunculus (*Potamogeton*, *Myriophyllum*, *Ranunculus aquatilis*) are all distributed in this way. Sometimes these growths settle in places where formerly no specimen of the kind had been seen for miles, and the fact may be easily confirmed that the distribution of their offshoots is actually brought about by flowing water in a very short time to great distances and in great abundance.

The distribution of offshoots in little brooks which flow down between Reeds and Rushes with a moderate fall, and scarcely ever overflow their banks takes place more quietly. A rapid flow occurs only in the middle of the channel, but near the bank, and especially in the small inlets, the water is almost as still and calm as in a closed-in lake. Here in these quiet spots are also to be found floating

plants brought by birds; their roots are either not fixed to the ground but sway about in the water, or they may be altogether absent; examples are, *Riccia fluitans* and *R. natans*, *Lemna* and *Wolffia*, and in tropical regions *Azolla* and *Pistia*. All these multiply very rapidly. While they continually branch at one end, forming spreading lobes and sprouts, they die away on the other, the result being of course a separation into several pieces, *i.e.* into offshoots. These fragments spread themselves like a green mosaic over the surface of the water. As the offshoots increase in numbers a certain number of them will extend beyond the calm inlet by the bank into the flowing water in mid-stream. Here they are hurried away by the current, and it often happens that they travel some distance before they are again stranded in some calm spot near the bank to form again the starting-point of a fresh aggregate of offshoots.

Rain-water also plays an important part in the distribution of offshoots. Those of the widely spread Liverwort, *Marchantia polymorpha*, so frequently met with on damp earth, are especially noticeable in this respect. Their development is represented in fig. 196, p. 23. On the surface of the dark-green leaf-like thallus of this Liverwort cups arise, at the base of which papillæ give origin to plate-like brood-bodies (gemmae, *cf.* figs. 196² and 196³). Other papillæ behave differently, and undergo only slight enlargement. The heads of these latter then swell up forming a gelatinous mass, and as this swells up it raises the green gemmæ higher and higher out of the bottom of the cup (fig. 196²). At last they get close to the edge and are washed out of it by the rain. The offshoots of other Liverworts are also chiefly distributed by rain-water, as for instance the gemmæ which arise in the crescent-shaped pockets of *Lunularia*, and in the flask-shaped cavities of *Blasia pusilla*. The pairs of cells which arise on the upper surface of *Aneura multifida*, the single cells which become detached from the edge of the fronds of so many Liverworts, the multicellular offshoots which are given off by *Radula complanata* so common on the bark of trees, the round cell-plates growing on the edge of the leaf-like thallus of *Metzgeria pubescens*, and finally the ball- and disc-shaped groups of cells which develop on the surface of the leaves of numerous Mosses (*e.g.* on various species of the genera *Leucobryum*, *Grimmia*, *Zygodon*, *Orthotrichum*, *Barbula*, *Calymperes*). In many of these cases the small offshoots are detached as well as distributed by the action of rain-water, but in others the loosening occurs before the rain begins, and in *Blasia* and *Aneura*, as well as in *Marchantia*, the offshoots are first separated by mucilaginous membranes, and are thus raised up from their attachment. Not until afterwards are they washed out and distributed by the falling rain. These small offshoots can of course also be carried away from their place of origin by strong gusts of wind. Even breathing strongly on them is sufficient to detach the uppermost gemmæ of *Marchantia*, but in dry air and in dry soil they rapidly shrivel up and perish. The distribution by currents of air is therefore not attended by success, but the offshoots of the Liverworts and Mosses washed out by showers of rain immediately begin to grow, and quickly attain to further development. This mode of distribution plays an

important part in the covering of tree-trunks with Mosses and Liverworts. A small patch of *Radula*, *Metzgeria* or similar plant having once taken hold, when a downpour of rain beats upon the trunk quantities of tiny ball- and disc-like offshoots float away to be caught again by projecting irregularities of the surface; indeed the rapid covering of old trunks with green carpets and mantles of Liverworts and Mosses is for the most part effected by rain-water.

It is comparatively seldom that bud- and sprout-shaped offshoots are distributed by rain. But there is one very interesting example of this, viz. the widely-spread Lesser Celandine (*Ranunculus Ficaria*), a single plant of which is shown in fig. 343³, p. 460. In the axils of the foliage-leaves of this plant are developed offshoots which have the form of small tubers, and which are not unlike the youngest stages of small potato-tubers (fig. 343⁶). When the leaves and stalk of the Lesser Celandine begin to turn yellow and wither in the early summer, the tubers break away from the stem and fall to the ground. There they usually escape observation, since they are hidden by the yellowing foliage; but should there come a heavy storm of rain the withered leaves are pressed down on to the soil by the force of the rain-drops, and the scattered tubers become visible. Sometimes the impact of the falling rain-drops hastens the detachment of the tubers from the mother-plant. When the rain is so heavy that the water flows away in the form of small rivulets, the loose tubers are washed off in abundance. A sudden downpour of rain in a region abundantly overgrown with Lesser Celandine is sufficient to float away numbers of the tubers, and heap them up on the borders of irrigation channels when the rain disperses. In such places the quantity of tubers which have floated together is often so large that one can hardly gather them in one's hands. In this way arose the idea that the tubers had fallen from heaven with the rain, and the myth of a rain of potatoes.

The small tubers which arise in the axils of the leaves of *Gagea bulbifera* (cf. fig. 343¹, p. 460), a plant growing on the steppes of Southern Russia, are distributed by rain-water just like those of the Lesser Celandine. This brings us to the question of the much-discussed manna-rain in steppes and deserts, which in reality is nothing but the distribution of the offshoots of a Lichen, viz. the Manna-lichen. This Lichen, which was termed *Lichen esculentus* by the older Botanists, but in recent times has been referred to the genera *Urceolaria*, *Lecanora*, *Chlorangium*, and *Sphærothallia*, and which apparently consists of three species, viz. *Lecanora esculenta*, *L. desertorum*, and *L. Jussufii*, is spread over an enormous region in south-west Asia, and extends as far as the south-east of Europe and the north of Africa. This Lichen is met with in the neighbourhood of Constantinople, in the Crimea and Caucasus, in Persia (whence the illustration at page 695), also in Kurdistan, Arabia, and the Anatolian high land from Bulgar Dag in the Taurus (where it is very often met with at a height of 2700 metres above the sea), and finally in the Sahara and the deserts of Algeria. It first forms thick wrinkled and warted crusts on the stones, preferably on small fragments of limestone lying about; the outer colour of the crust is a grayish yellow, while on breaking it appears as

white as a crushed grain of corn. As they get older the crusts become rent, and separate either partially or wholly from their substratum. When they first become loosened the edges of the detached portion become somewhat rolled back. The rolling then continues, and ultimately the loosened piece forms an elliptical or spherical warted body with a very much contracted central cavity. Small stones are sometimes imprisoned in this way within the cavity of the sphere, in which case the weight of the loose Lichen is correspondingly increased, but as a rule the hole is filled with air, and when dried the pieces weigh very little. Ten loose pieces of Manna-lichen, each as large as a hazel-nut, weighed 3.36 grams, and the weight of a single piece therefore was on an average only .34 grams. It is easy to see that the loose portions will be rolled about by the wind, and that a storm will sometimes sweep them up from the ground and carry them hither and thither through the air. This method of distribution appears to be the prevailing one in regions where the supply of water is not abundant in the rainy season, and where violent storms rage from time to time. That this is so is confirmed by the circumstance that the Manna-lichen after the storms lies chiefly piled up behind the low bushes and undergrowth, *i.e.* just where the force of the storm has been to some extent broken, and where the shifting sand has been heaped up into little hillocks. Where a period of heavy rains succeeds the long dry summer, however, and where such a quantity of water falls on the parched land that it cannot all be absorbed, some of the rain collects into small rivulets. These carry away with them everything which is movable and capable of floating. The turbid rivulets flow down over the inclined soil to the lowest parts of the country and there unite into larger streams, or if it can find no outlet the water remains for some time in the hollows as small pools and puddles, and deposits there the mud and vegetable debris it has carried with it. The latter is more especially the case on the steppe soil overstrewn with small stones where between the slight elevations there is a labyrinth of shallow channels and winding depressions resembling ploughed land. In such regions the Manna-lichen is chiefly washed into the depressions by the rain-water, and in some years in such quantity that they form heaps a span high, and a single man can in a day collect 4-6 kilograms (about 12,000-20,000 pieces, varying in size from a pea to a hazel-nut). This is especially the case in the steppe region and in the high lands of South-west Asia, where the Manna-lichen is used as a substitute for corn in years of famine—being ground in the same way and baked into a species of bread. That the rain-water is the agent which transports the Lichen in these regions is beyond doubt, because the pieces heaped up in the hollows are not in the least rubbed on their outer surfaces as would certainly be the case if they had been rolled and dragged even for only a short distance over stony ground. It is also remarkable that all the great so-called rains of manna, of which news has come from the East to Europe, especially those of the years 1824, 1828, 1841, 1846, 1863, and 1864, occurred at the beginning of the year between January and March, *i.e.* at the time of the heaviest rains. When we remember that the inhabitants of the district actually thought that the manna had fallen from heaven, and quite overlooked the

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fact that this vegetable structure grew and developed (although only in isolated patches and principally as crusts on stones) in the immediate neighbourhood of the spots where they collected it, we need not be surprised at the conclusion of our own peasants who thought the tubers of the Lesser Celandine had fallen with the rain from heaven. It should be mentioned that the manna sent to the Israelites on their journey out of Egypt to the Holy Land is identical with the Lichen described here and figured on page 695, and the older view that the manna of the desert was the sap of a Tamarisk (*Tamarix gallica mannifera*) exuded under the influence of a parasite is without any foundation.

Spores take the first place among the reproductive bodies which are distributed by wind. Many Ascomycetes develop some of their spores by abstriction from the free ends of special hyphæ. These rise up into the air from the substratum, which is permeated or covered by the mycelium. In this way the separated but loosely-adhering spores can be carried away by the slightest atmospheric movement. In the Moulds known as *Aspergillus* and *Penicillium*, whole series of spores are cut off from the end of each hypha (see figs. 193⁴, 5, 8, 9, p. 18), and as they are crowded closely together a single breeze carries off innumerable quantities of spores. By breathing only lightly on the small forest-like colonies of supports the spores are whirled as dust into the air, and as they are extremely light they not only remain a long time suspended in it, but even in perfectly still air are carried sometimes up, sometimes down, by the currents due to slight differences of temperature, again being carried horizontally or whirled along until at last they settle, and become the starting-point of a new Mould formation. The spores abstricted from the ends of the so-called sterigmata in the Hymenomycetes (see figs. 389 and 390⁷) may also be detached and carried away by wind, but apparently most of the spores in these Fungi separate spontaneously in calm air and fall to the ground, covering it with a delicate layer of dust, to be afterwards carried away from this resting-place by breezes.

The spores of Ustilaginæ and those in the æcidia of Uredinæ (see p. 686) are at first covered with delicate membranes and sometimes inclosed in special receptacles. As soon as they are mature they form a powdery mass, which bursts through the covering membrane, and the now exposed spores are blown away as dust by the wind. If they have developed in deep receptacles shaking is necessary before they can be blown away. The spores then fall from the mouth of the receptacle into the currents of air. In many Myxomycetes and Gasteromycetes (see fig. 367², p. 618, and fig. 391², p. 690) delicate twisted threads called the capillitium are developed simultaneously with the spores. The web of threads with the spores between them is inclosed in a membrane (see fig. 449¹). When this membrane bursts at maturity and the receptacle is thrown open only the spores in the immediate neighbourhood of the opening can be blown away by the wind, the deeper ones being held back by the capillitium. The lower layers of the capillitium are then raised by the action of dry winds, and thus quantities of new spores are continually carried from below up to the opening. In this way it happens that the spores of these plants are only

distributed in small detachments, and only at a suitable time, *i.e.* when a dry wind is blowing. A similar contrivance is exhibited by the Muscineæ in the Marchantiaceæ, Anthocerotaceæ, and Jungermanniaceæ. Peculiar filamentous, very hygroscopic cells with spiral bands of thickening on the cell-wall, are found with the spores in the receptacles of these plants (see p. 696). These have been called elaters, because it was thought that their movements caused the ejection of the spores. Their significance, however, rather lies in the fact that they serve to hold the spores together after the opening of the receptacle, and only expose them by degrees to the wind. They also help to burst open the receptacles, but that hardly concerns us just now.

Only three of the most striking of the varied contrivances for spore distribution by wind in Mosses (which are destitute of elaters) will be here described. First, those which are observed in the Andreaeaceæ (see figs. 450¹ and 450²). Here the capsule opens by four longitudinal clefts which, however, do not extend quite to the free end, and the four pieces into which the wall is thus divided may be compared to the staves of a barrel joined together at the top. In damp weather they become approximated, so that the clefts are closed (fig. 450¹). In dry weather the valves become arched, the clefts widen, and the spores may be blown out from the interior of the capsule by the dry wind (fig. 450²). The distribution of the spores is effected quite differently in the Polytrichums, one species of which is illustrated



Fig. 449.--*Trichia clavata*.

¹ The membrane of the sporangium has burst, and the capillitium has bulged out raising up the spores embedded between its threads and exposing them to the wind; $\times 20$. ² Threads of the capillitium with the spores lying between them; $\times 250$.

in figs. 450^{3,4,5,6,7,8}. After the roof (operculum) which formerly surmounted the capsule has fallen off a delicate whitish membrane comes into view, which is held fast by the points of numerous sharp teeth, and is stretched like the skin of a drum over the mouth of the capsule with its annulus. If rain and dew moisten the Moss the teeth are seen to be much bent inwards, the membrane lying upon the annulus, and completely closing the receptacle (fig. 450⁵ and 450⁷). But in dry air, especially when a dry wind is blowing, the teeth turn rather outwards, raising the membrane above the annulus, and thus small holes are left between the teeth through which the spores can escape (figs. 450⁶ and 450⁸). The same dry wind which causes the alteration in the position of the teeth now shakes the spores out of the capsule, which is borne on an elastic seta. *Grimmia ovata*, one of the Bryaceæ (see figs. 450⁹ and 450¹⁰), may be taken as the type of a third contrivance for exposing the matured spores to the wind in dry weather, retaining them in the receptacle when it is damp and protecting them there from the injurious effects of moisture. The circular mouth of the pipe-bowl-shaped receptacle is furnished with

teeth, each of which terminates in a free point. The tissue of these teeth is hygroscopic, and their direction and position alter to a surprising extent according to the degree of humidity of the air. In damp weather the teeth are so close together that they completely shut the capsule (fig. 450⁹), but in dry weather they bend outwards (fig. 450¹⁰), and the spores are shaken out of the capsule and scattered by the wind.

We shall have to describe presently how the sporangia of most Ferns dehisce

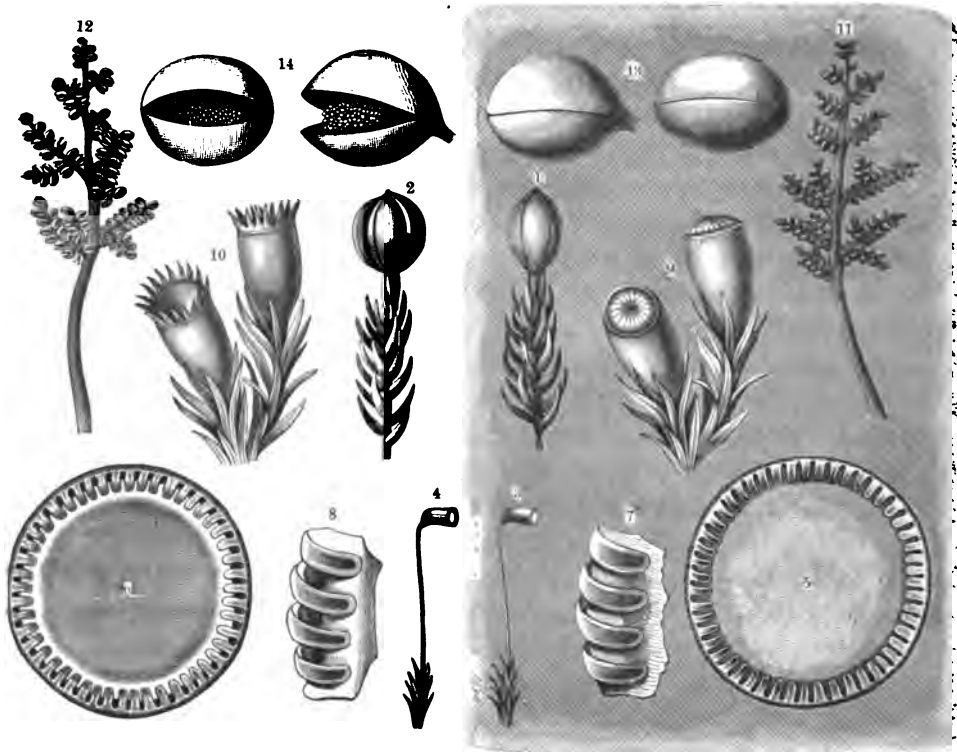


Fig. 450.—Dispersal of spores by wind.

¹ Spore-capsule of an *Andropogon* in damp weather. ² The same in dry weather. ³ Spore-capsule of a *Polytrichum* in damp weather. ⁴ In dry weather. ⁵ The spore-capsule of a *Polytrichum*, the edge of the mouth beset with teeth and covered with a membrane, in damp weather. ⁶ In dry weather. ⁷ A part of the peristome more highly magnified, in damp weather. ⁸ In dry weather. ⁹ Spore-capsule of a *Grimmia* in damp weather. ¹⁰ In dry weather. ¹¹ Racemose sporangia of a *Botrychium* in damp weather. ¹² In dry weather. ¹³ A single sporangium of this *Botrychium* enlarged, side and front view, in damp weather. ¹⁴ In dry weather. ³, ⁴, ¹¹ and ¹² nat. size; the others enlarged.

suddenly so as to scatter the spores. In such Ferns the sporangia are developed on the under side of the frond, and this position protects them excellently against any injury which might befall them from rain or dew. But there are some Ferns whose sporangia are exposed to both rain and dew, and whose spores are not suddenly scattered by the bursting of the sporangia. Among others, the Moonwort (*Botrychium*) may be mentioned. Its branched spike of sporangia is represented in figs 450¹¹ and 450¹². The elliptical sporangia of the Moonwort open by a transverse slit, but the two valves thus formed only separate in dry weather (figs. 450¹²

and 450¹⁴) when the spores may be shaken out and blown away. As soon as the sporangia are moistened the two valves immediately shut together (figs. 450¹¹ and 450¹⁸) and obviously the spores can no longer be shaken out. A similar opening and shutting of sporangia according to dryness or moisture may also be observed in the Lycopodiaceae (see fig. 405⁴, p. 716).

A similar phenomenon may also be observed in the sporangia of the Horse-tails (see fig. 403⁴, p. 712). Here not only the sporangia but the spores themselves present a very different appearance according as they are dry or damp. The wall of these spores consists of several layers, of which the outermost splits up spirally to form two arms which remain joined to the spore at one spot. In dry weather the two spiral bands, which are arranged in the form of a cross, unroll (see fig. 451¹) and constitute four appendages which afford enough purchase to the wind to enable the comparatively large and heavy spores to be carried away. If the spores fall on to

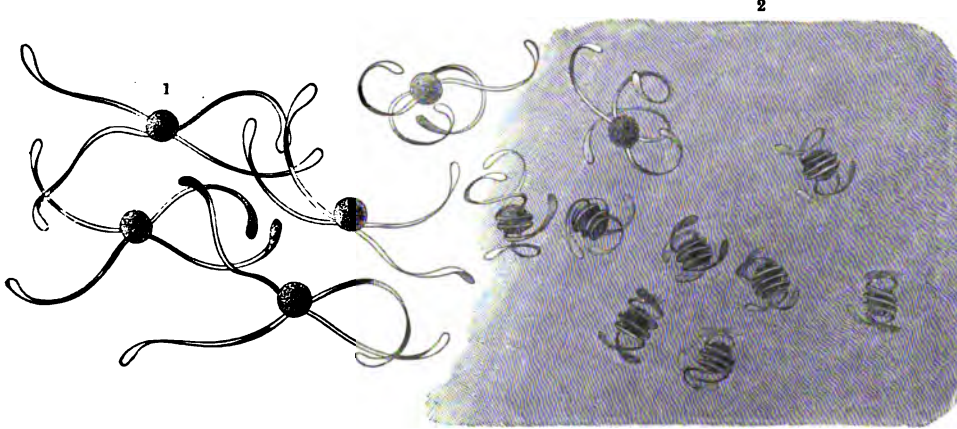


Fig. 451.—Spores of the Horse-tail *Equisetum Telmateja*.

¹ In dry; ² in moist condition; $\times 25$.

some spot of earth which, on account of its dryness, is not suitable for their germination the wings remain widely outspread. The next gust of wind raises them up again and carries them to another place. If, however, the resting-place is moist, and if the conditions are favourable to the growth of the *Equisetum*, the bands roll up spirally (see fig. 451²). In this way the spores may become fastened to a projecting object, and if this should not be the case at least the rolling up of the bands produces a diminution in size, and the spores are not easily again blown away from a suitable damp resting-place. Another explanation as to the function of these structures has also been offered, namely, that by means of the repeated expansions and contractions of these hygroscopic arms the spores are linked together as it were arm in arm. Further reference to this will be found at p. 713.

The soredia of Lichens must also be mentioned as asexual reproductive bodies which are distributed in enormous quantities by currents of air. To the naked eye they look like a floury dust deposited in places on the Lichen thallus. These dusty masses are built up of green cells, either solitary or in groups, which are wrapped

round by colourless hyphal threads. They arise in the interior of the Lichen body, and are ultimately pushed out on the surface by the rupture of the pustules in which they arise. The wind raises and carries them away, and if they happen to fall into the cleft of a rock or into the crevices on the bark of a tree they immediately grow up into a new Lichen body which agrees in every particular with the parent plant and is itself able to again produce soredia. The genera *Stereocaulon*, *Evernia*, and *Pertusaria* are especially noted for their abundant formation of soredia. The shrub-like, branched *Stereocaulon coralloides* is often so thickly covered with soredia that the whole Lichen looks as if it had been strewn with coarse meal, and *Evernia furfuracea*, growing on the bark of old trees, owes its name to the fact that it seems to have been overstrewn with meal.

It has already been stated that the multicellular offshoots (gemmæ or thallidia) of Mosses and Liverworts may be distributed by wind as well as by rain-water. We might mention as examples, *Aulacomnion androgynum*, *Calypogeia Trichomanes*, *Scapania nemorosa*, *Jungermannia bicuspidata*, and *Blasia pusilla*, whose offshoots are borne on special erect supports (see figs. 196¹⁵, 16, 17, 18, p. 23), or *Syrrhopodon scaber*, which grows in Central America, and whose thallidia are formed on the apex of the leaflets (figs. 196¹², 13, 14). The Moss *Tetraphis pellucida* (figs. 196⁴, 5, 6), which grows commonly on rotten tree-trunks in Pine forests in mountainous regions, might also be mentioned. It develops multicellular disc-shaped gemmæ at the top of certain erect shoots. The discs are supported on delicate filamentous stalks and are embedded in a cup of closely crowded leaflets (figs. 196⁵, 6, 7, 8). After the supporting threads have withered and the small multicellular discs have become detached, a slight shaking by the wind is sufficient to make the gemmæ fall out and to scatter them. The same breeze which shook the stem now whirls the tiny green discs far over the forest ground and transports them to other places of attachment where they continue their development.

In some Mosses whose little leaves are very brittle when dry, for example, in *Campylopus* (see fig. 196¹¹), the leaves themselves serve as offshoots. How the detachment of these leaflets is brought about is to some extent an enigma; apparently they separate and are thrown off spontaneously, not unlike the foliage-leaves which fall from the branches of trees in autumn. This is immaterial to the question under consideration here, however. This much is certain, that in the remotest mountain ravines, and on inaccessible ledges in precipitous places where the disturbance of passing animals is quite impossible, the turf-forming crowded stems of *Campylopus* always carry detached and partially split leaflets which adhere loosely to the support. When after a few dry days a storm rages through the ravines, these loose leaflets are torn away, and do not again come to rest until they are far distant from the spot from which they were taken. The offshoots of Mosses composed of groups of cells, and the last-mentioned detached leaves which function as offshoots, do not grow up immediately into new Moss-plants, but first of all develop protonema-like cell-filaments, and it is from these that the young Moss-plants originate.

It also happens that whole Moss-plants with elongated axis, numerous leaves,

and abundant rhizoids are distributed by wind. This is observed in Mosses of very different genera (e.g. *Leucodon sciuroides*, *Thuidium abietinum*, *Hypnum rugosum*, *Myurella julacea*, *Conomitrium Julianum*, *Anectangium Sendtnerianum*). The development of this form of offshoot is shown in figs. 156⁹ and 156¹⁰, p. 23, in *Leucodon sciuroides*, which is common on the bark of old trees. In the angles made by the leaves with the axis of old shoots, buds first arise which grow into miniature Moss-shoots. These tiny shoots then become loosened at their base, and push up towards the top of the leaves supporting them. This happens more especially in rainy weather. When it is dry their leaflets lie close to the axis, but when saturated with moisture they stand out and bend backwards, and thus raise themselves out of the deep niche in which they have hitherto been concealed. Many of these loosened shoots are without doubt carried away by rain-water, and so transported some little distance, but most of them are whirled off by the wind, and carried far away over mountain and valley.

Bud-shaped offshoots, which become detached from the aerial portions of plants, and whose distribution is effected by wind, are comparatively rare. A remarkable instance is furnished by the Club-moss *Lycopodium Selago* (see fig. 343², p. 460). This plant, which is found in mountainous districts in the Northern Hemisphere of the Old and New Worlds, forms buds in the axils of its stiff, dark-green leaves, especially near the top of the shoot, which might, at first sight, be mistaken for small winged fruits. These buds are so provided with little leaves as to offer a good purchase to the wind, and by this means they are transported (cf. fig. 343⁵). The North American *Lycopodium lucidulum*, *L. reflexum*, *L. Haleakala*, *L. serratum*, *L. erubescens*, behave in just the same way as *Lycopodium Selago*, and it is not improbable that many other allied species exhibit this kind of offshoot.

Most detached bud-like offshoots, which develop in the axils of foliage-leaves and bracts on larger plants, e.g. on the bulbiferous Coral-wort (*Dentaria bulbifera*; see p. 461), can hardly be said to be distributed by wind. They are spherical or ovate, and not flattened like those of the Club-moss, and they are too cumbrous for transport on the wings of the wind. And yet the wind plays an important part in the distribution in such cases. The bulbils are borne on fairly stiff shoots, and the nature of their attachment is very fragile. Thus, as the shoot rebounds after the blast, many of the bulbils become detached, and are jerked away to a considerable distance.

There are three types of offshoots which are jerked from the plant in the above-mentioned manner. First, those which have the form of closed buds or small bulbs, and which consist of a very much abbreviated stem or bulb-axis, and a few much-thickened scale-leaves filled with reserve materials. These are found in the bulbiferous Coral-wort, which grows commonly in Central European Beech forests, and has been selected as typical; on the bulbiferous Saxifrage (*Saxifraga bulbifera*), widely distributed in meadows in Eastern Europe; on several Lilies (e.g. *Lilium bulbiferum*, *tigrinum*, and *lancifolium*); and on the Persian Gagea (*Gagea Persica*), in the axils of the upper foliage-leaves; on *Foucroya gigantea*, growing on the

Antilles, and above the disc-shaped bracts on the top of the stalk on a considerable number of species of *Allium* (e.g. *Allium Moly*, *vineale*, *oleraceum*, *carinatum*, *arenarium*, *Scorodoprasum*, *sativum*). A second type, growing in the axils of bracts on the upper part of the stem, is shown by *Polygonum bulbiferum* and *viviparum*, natives of the far north, and of the Alpine regions of Europe and the Himalayas (see figs. 452¹, 2, 3, 4, 5, 6, 7, 8). These are not bulb-like structures, but small tubers or corms with a minute terminal bud projecting like a little horn, and the tissue of the tuber is abundantly filled with starch and other reserve materials (see figs. 452⁹ and 452¹⁰). The third type is observed in species of the genus *Globba*, belonging to the Scitamineæ, more especially in the East Indian *Globba bulbifera* and in *Globba coccinea*, which grows in Borneo. These rare plants develop offshoots in the axils of bracts on the uppermost part of the rigid stem. They consist of a small bud, from whose minute axis a thick, fleshy root filled with reserve materials grows down, so that in reality the chief part of the offshoot consists of a root-structure.

When the closed bulb-like offshoots, tubers, or buds with thickened roots have been thrown from the wind-swayed stem they remain unaltered in the spot where they have found a resting-place through the whole winter, or the whole dry period of summer. At length, when the most suitable time of year arrives, little absorbent roots make their appearance (see fig. 452⁵) at the expense of the stored-up reserve materials, and these fix the offshoots in the soil and convey fluid nourishment to them. The axis of the offshoot elongates and grows into a stem, putting out leaves and forming a new independent plant.

The entire sprouts, which are detached from aërial stems and become offshoots, can obviously not be transported very far by wind. They are much too heavy, and offer no suitable hold to the wind, which can only influence them by shaking the stem on which they are supported, or by rolling them along after they have fallen to the ground. In the former case the sprout-like offshoots are jerked off, and the action of the wind is therefore only indirect. Some plants bear side by side on the same stem tubers with undeveloped buds, and also some whose buds have begun to grow into sprouts, and have developed green foliage-leaves. These form a connecting-link between the groups just described and those we are now about to consider. One of them is the already mentioned viviparous *Polygonum* (*Polygonum viviparum*, fig. 452), in which it often happens that all possible stages of development occur close together on a single spike.

In Grasses especially it is often the case that the offshoots when ready to be detached have the form of developed, leafy sprouts. In the Grasses of the Arctic flora belonging to the genera *Poa*, *Festuca*, and *Aira*, the formation of leafy sprouts which become offshoots is so usual that in places the plants bearing offshoots are more common than those bearing flowers in their panicles. On our high mountains also there grows a grass (*Poa alpina*, cf. fig. 342⁸, p. 455), in which the panicles as often bear offshoots as flowers. On the plains of Hungary flourishes a species of Meadow-grass (*Poa bulbosa*), in which the same thing happens to such an extent that in the many thousand plants which cover the ground all the panicles develop

offshoots exclusively. The detachment takes place in different ways in these "viviparous" Grasses. Usually the sprouts loosen from the erect panicles of the



Fig. 462.—*Polygodium viviparum*.

¹ Entire plant; one spike bears flowers only, the other carries tubers on the lower half and flowers above. ² A whole plant whose spike bears tubers only. On some of the tubers small foliage-leaves have already developed. ³⁻⁵ Fallen tubers in successive stages of development; nat. size. ⁹ A fallen tuber magnified. ¹⁰ The same in longitudinal section.

swaying haulm, and are scattered by the wind, but sometimes the separation does not occur until the stem is bent down to the ground with the weight of the crowded offshoots in the panicle. In this case the offshoots strike root where the panicle

touches the soil, and the result is that closely-crowded groups of new plants grow up round it. The same thing may be observed in *Chlorophytum comosum*, a native of the Cape often cultivated as a basket plant by gardeners under the name of *Cordyline vivipara*. In this plant leafy shoots are very regularly developed in the floral region instead of flowers, and as these increase in size and become heavier, the long, comparatively slender and very supple stem which bears them sinks down so that the sprouts are suspended on a green thread. If the ground below is suitable the pendent shoots which have meanwhile developed roots may settle there. If they do not come into contact with any suitable soil they remain a long time swaying in the air, growing and themselves forming long, thin stalks in their turn in whose floral region fresh, leafy sprouts with roots arise, and years after three or four generations of shoots connected together by a slender green stalk may be seen hanging down for the length of a metre. At length one or other of the swaying and wind-tossed sprouts strikes firm ground and takes root, separating itself from the old plant, or it falls like the fruit from a tree and rolls down below until it finds a place of settlement possibly at a considerable distance from the old plant.

Among the Rushes also there are many species which develop pendent sprouts. In one species which is very widely spread over Northern Europe, viz. *Juncus supinus*, it is much more usual to find sprout-like offshoots in the floral region than flowers. In many of the Saxifrages of the far North, viz. in *Saxifraga stellaris*, *S. nivalis*, and *S. cernua*, very reduced shoots with small rosettes of foliage-leaves are formed on the terminal branches of the floral axis, or bulb-like buds arise in the axils of the bracts on the upper part of the stalk which, like those of the viviparous *Polygonum*, send out green foliage-leaves before they fall or become loosened (see figs. 342¹, 2, 3, 4, 5, 6, 7, p. 455). *Sedum villosum*, which grows on moors, develops short, leafy sprouts with thread-like axis in the axils of the stem-leaves. As soon as the stem begins to wither these sprouts loosen and are carried to a short distance by gusts of wind. They send out delicate roots as soon as they find a resting-place and new plants are established.

A very peculiar mode of detachment and distribution of sprout-like offshoots is found in many species of House-leek (*Sempervivum*). The *Sempervivum soboliferum* illustrated here may be taken as an example. The thick, fleshy leaves of this plant are arranged, as in all House-leeks, like rosettes on abbreviated axes, and the new rosettes are always laid down as minute buds in the axils of the rosette-leaves. From these buds proceed thread-like runners, furnished with small adherent scales, ending in a reduced shoot. The crowded leaves of this reduced shoot enlarge, forming a small rosette, the leaves being folded so closely together that the whole structure has a spherical form. For some time the round rosette is nourished by means of the filamentous runner from the old plant, but afterwards the runner withers and dries up and the rosette breaks away from it. It is now quite separated from the parent plant (see fig. 453). A gentle breeze is sufficient to roll along the small detached balls; and as the House-leeks in question choose

as their habitat narrow ledges in rocky places, it is inevitable that some of the separated rosettes should fall over the steep wall, and should not come to rest till they have travelled a considerable distance from the mother-plant. Roots are soon developed from the base of the detached rosettes, by which they become fixed to the substratum. Usually a parent plant produces 2-3 rosettes, but frequently as many as six, and the neighbourhood of the terraces overgrown with the species of House-leek figured, and with other allied species (*Sempervivum arenarium*,

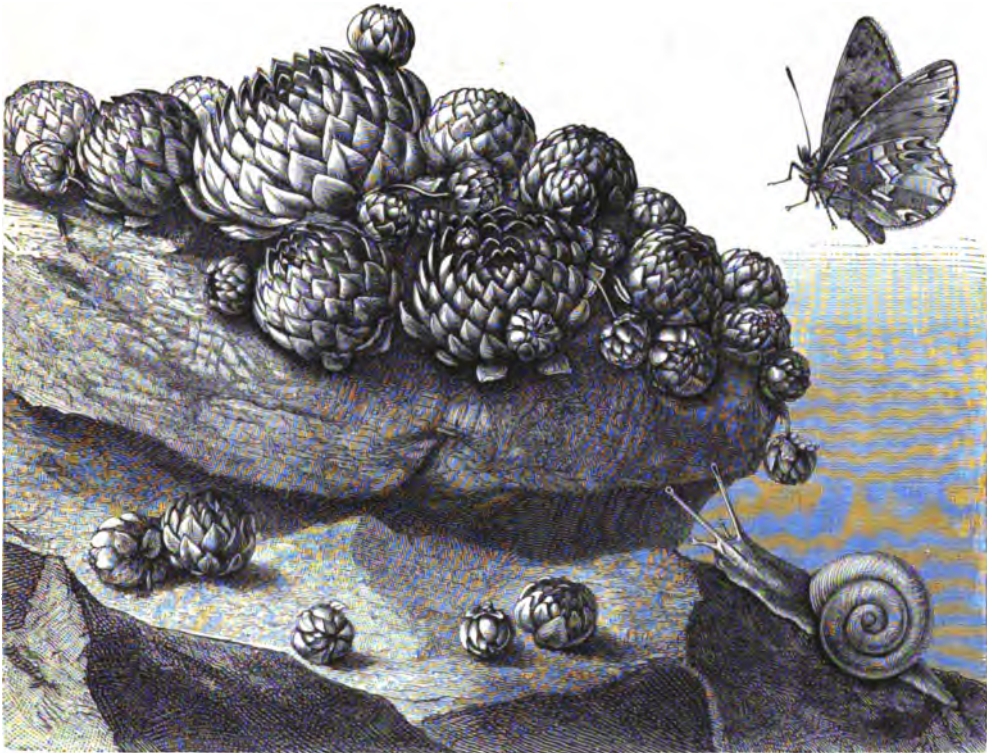


Fig. 453.—*Sempervivum soboliferum*. On the lower step of the rock lie five ball-shaped offshoots which have become detached from the upper rocky platform and have rolled down. The butterfly and snail are introduced into the picture to show the true proportions of the offshoots.

S. Neilreichii, *S. hirtum*) often looks as if it had been sown with the ball-like rosettes, which have rolled down.

Sedum dasyphyllum (see fig. 454¹), which grows in rocky crevices and in the niches of old stone walls, develops offshoots partly in the floral and partly in the foliage region. In the floral region the offshoots originate by the metamorphosis of floral-leaves into foliage. Instead of flowers there are small rosettes (fig. 454⁵) of thick, ovate, green scales, like those which take the place of flowers in *Saxifraga nivalis* and *S. cernua* (cf. p. 455). These rosettes in the autumn break away from the flower-stalks, and behave just like those of *Sempervivum*. In the foliage region the offshoots arise in three ways. In the axils of the uppermost leaves there is formed a bud which is hardly perceptible to the naked eye. It is embedded in the

shallow depression on the upper side of the thick leaf, and possesses 2-3 leaflets about .5 mm. in diameter (fig. 454²). In the axils of the lower foliage-leaves short sprouts are formed, whose axes are furnished with fairly large crowded rosette-shaped leaves (fig. 454³). In the axils of the lowest arise rudimentary sprouts, with an elongated thread-like axis bearing 8-14 thickly-crowded leaflets at its end (fig. 454⁴). As soon as the stem carrying the flowers begins to wither, the foliage-leaves and the buds or sprouts in their axils loosen from it and fall to the ground. The succulent, very turgid, almost hemispherical leaves are comparatively heavy, and if the spot where they first fall is sloping they do not lie still, but roll down

until they are caught by some projecting ledge, or a mossy cushion, or arrive on level ground. Since they carry with them the buds and sprouts formed in their axils, they to a certain extent function as a means of transport. As soon as the offshoots come to rest, they develop rootlets at their base at the expense of the reserve materials of the detached succulent leaf. Rootlets are often formed even while the leaves are still adhering to the decaying stem. It is worthy of note that the aqueous tissue of the fallen leaves also plays a part in the establishment of these offshoots. If the spot where they have come to rest is exceptionally dry, as is usually the case in places where *Sedum dasyphyllum* grows, the



Fig. 454.—The formation of offshoots in *Sedum dasyphyllum*.

¹ Entire plant; nat. size. ², ³, and ⁴, Offshoots which have developed at different levels on the stem in the axils of the leaves. ⁵ Offshoots from the floral region.

supporting leaf may for a long time provide the water necessary for the maintenance of the offshoot, and so protect it from perishing.

The formation of sprout-like offshoots is very remarkable in the *Kleinias*, natives of the Cape, which belong to the Compositæ. Some species of this genus, viz. *Kleinia neriifolia* and *K. articulata*, remind one very much in their appearance of certain Cacti. The fleshy, much-thickened cylindrical branches are connected with one another by thin strands, and the whole plant looks as if it had been constricted at intervals by ligatures. The strands joining the heavy cylindrical branches break at the slightest pressure, and the upper shoots especially may be broken off even by a violent gust of wind. The result of the fracture at the constricted places, however, is that the branches fall to the ground. If the plant grows on a slope, the fallen cylindrical shoots roll down until they are stopped by a projecting stone or some other obstacle. When they come to rest they develop numerous roots

where they touch the ground, and at the same time send up new lateral branches from the opposite side, as shown in fig. 455. It should be mentioned that in *K. articulata* the roots often begin to develop before the branches have broken and fallen off, always appearing on the side of the shoot which is turned towards the soil. This also is shown in the figure.



Fig. 455.—The formation of offshoots in *Kleinia articulata*.

In all these instances the offshoots are detached by the force of the wind. Another method by means of which the same end is attained depends on the hygroscopic properties of the tissues concerned, and on the alternate swelling and contraction from this cause. Several Fungi of the group Peronosporæ, among others the unwelcome Potato-disease Fungus, *Phytophthora infestans*, multiply by spores formed on delicate hyphal threads, which are protruded from the stomata of the

host plant. These hyphal threads bifurcate, and the end of each branch swells up into a spore. The supporting hyphal branch then grows out again below each spore, elongates, and extends upwards, and pushes the spore on one side. The result of this oft-repeated process is a structure which resembles a small much-branched tree, with egg-shaped fruits hanging from the boughs. The hyphal branches, on which the spores are set like fruits, are cylindrical, stiff, and turgid in damp air, but in dry air, especially when they are ripening, they become ribbon-like and spirally twisted so as to resemble cotton-cells. They are extremely hygroscopic, and the slightest change in the humidity of the surrounding air is enough to increase or diminish their spiral torsion. Even mere breathing on them produces an alteration in the twisting, and if a rapid and marked alteration occurs in the hygroscopic condition of the environment, the branches with their hanging spores are whirled hither and thither, and the spores, which are only attached but slightly, are scattered in all directions. This cannot of course be seen except under unusually favourable circumstances, on account of the minuteness of the spores.

The shedding of the spores can be observed with the naked eye in the Mould *Pilobolus cristallinus*, one of the Mucorineæ, shown in figs. 456¹ and 456². The mycelium of this Mould consists of a colourless, much-branched tube, and grows on the excrement of horses and other mammals. Enlargements arise on the mycelium, and from each is produced a sporangial mechanism composed of two parts, a colourless, barrel-shaped, stalk-cell and a dark head. The latter contains a colourless jelly, which swells up in water, together with numerous spores, and is to be regarded as a sporangium. Its wall is covered with calcium oxalate, so that its elasticity is completely lost and it becomes brittle. The cell-wall of the barrel-like swollen stalk, however, remains soft and elastic. At the junction of the dark sporangium with its colourless stalk a circular layer of separation is formed. When the turgidity of the sporophore increases in consequence of the absorption of water from the mycelium the tension at last becomes so great that it causes a rupture round the circular line mentioned. At the same moment, however, the elastic wall of the part of the sporophore immediately below contracts, and the fluid contents are pushed out with great force. The push is transmitted to the dark sporangium above the split, and both the fluid contents of the club-shaped support and the entire sporangium are thrown off (see fig. 456²). The force of the explosion is so considerable that the dark mass is raised about a metre in height. The whole process, which, as we have said, may be seen with the naked eye, usually occupies 18-20 hours. The development of the mechanism begins at mid-day; during the night the spores are formed in the vesicle, and the next morning the explosion occurs as soon as daylight appears.

A no less interesting spectacle is afforded by the scattering of the unicellular offshoots, *i.e.* conidia, in species of the genera *Empusa* and *Entomophthora*. These live on the dead bodies of caterpillars, flies, aphides, and other insects, the commonest and best known being *Empusa muscæ*, which lives on the common house-fly. When a conidium of this *Empusa* falls on the body of the fly it puts out a tube which pene-

trates into the body-cavity, and there it divides up repeatedly, forming numerous cells throughout the body. The infected fly, sickening under the injurious influence of the Fungus and almost at the point of death, seeks for some quiet spot in which to die. It frequently chooses for its last resting-place a window pane, in which case it is possible to thoroughly investigate the further development of the Fungus. After the death of the fly the round cells of the *Empusa*, hitherto hidden in the body-cavity, grow out into long tubes which pierce the skin of the fly's corpse and appear as short club-shaped structures on the surface. A single egg-shaped conidium

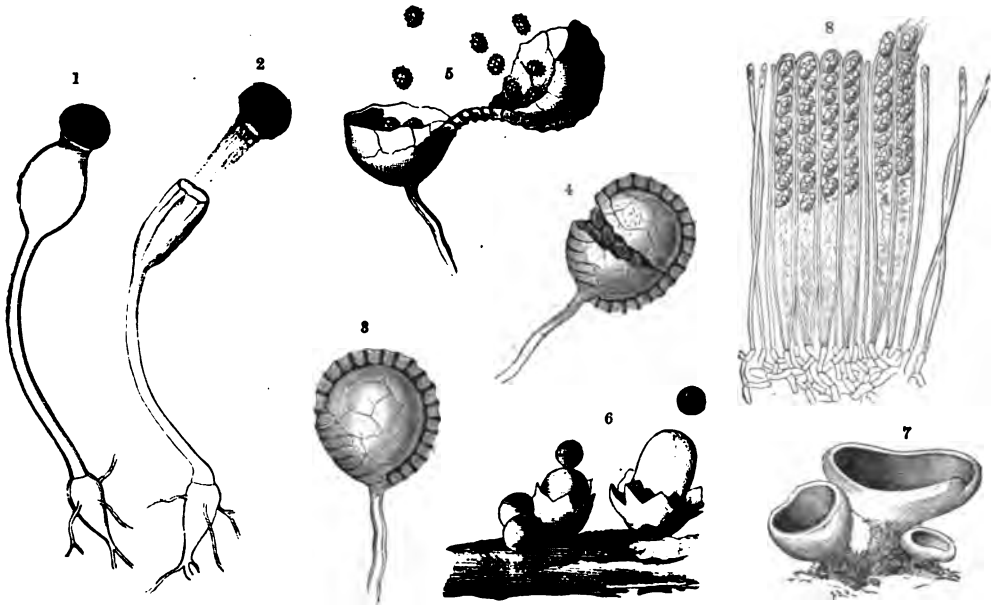


Fig. 456.—Distribution of spores by expulsive mechanism.

¹ *Pilobolus cristallinus* before the sporangium breaks away. ² The same at the moment when the sporangium is thrown off. ³ Sporangium of *Nephrodium Filix-mas* closed. ⁴ and ⁵ The same in the act of splitting and scattering the spores. ⁶ *Sphaerobolus stellatus* at the moment when the balls filled with spores are thrown off. ⁷ *Peziza aurantia*. ⁸ Longitudinal section through this *Peziza*. The spores are escaping from two of the asci. All the figures magnified

is then cut off from each club-like end of the tube, and this is thrown off in exactly the same way as the sporangium of *Pilobolus* (cf. fig. 383⁷, p. 672). Here, too, a place is formed for the splitting, and here again the mucilaginous contents are thrown off simultaneously with the conidium by the sudden contraction of the club-shaped end of the tube, and the conidium is thus always surrounded by a gelatinous adhesive mass (fig. 383⁸). The distance of the projection may be as much as 2–3 cm., which, considering the extraordinary minuteness of the conidia, is proof of great power. The dead fly then appears to be surrounded by a veritable halo of detached conidia which are firmly attached to the substratum (fig. 383⁶). This is to be accounted for by the fact that, as already stated, a part of the sticky mucilaginous contents of the club-shaped end of the tube are thrown out with the conidia. This serves as an adhesive material, and causes the conidia to adhere particularly firmly to glass window panes. If a living fly which happens to be near is struck by the projected

conidia, they stick to it so firmly that it cannot succeed in getting rid of them or freeing itself in spite of all its attempts. Each adhering conidium then again sends a tube into the body-cavity of the fly, and the development is repeated in the way just described. The same thing happens in *Entomophthora radicans*, which lives on the caterpillar of the Common White butterfly (*Pieris Brassicæ*). It is represented in figs. 383^{1, 2, 3, 4, 5}, p. 672). Tufts of delicate thread-like hyphæ come out of the body of the caterpillar for the purpose of forming conidia (fig. 383⁶). These gradually form a thick web round the dying caterpillar, and at a cursory glance one might think it had woven its covering and changed into a chrysalis (fig. 383²). The tubes, looking like fine threads, unlike those of *Empusa*, are here much-branched, and actual tufts of hyphæ arise from whose ultimate somewhat swollen ends the long, sticky conidia are abstricted and scattered (figs. 383⁴ and 383⁵).

The scattering of the spores from the asci of Ascomycetes takes place in a characteristic manner. They are developed in groups of 2, 4, 8, 16, or 32 in the tubular asci, and numerous thread-like hyphal ends, the so-called paraphyses, occur between the asci (see fig. 456⁸). In addition to the spores the asci contain protoplasm and cell-sap, and are considerably distended by the large amount of the latter. As the dilatation increases the asci burst, and their cell-wall, which is at a high tension, exercises a powerful pressure on the cell-contents, which are extruded with great force. The place where the rupture of the wall of the ascus occurs is determined beforehand, so that the extrusion of the cell-contents and spores always takes place in the same way. In many species the top part of the ascus-wall is raised like a lid, in others a transverse splitting occurs, and in others again the spores are ejected through a small circular hole. A slight shake or a dry breeze is quite enough to cause the ejection, and in *Spatularia flavida*, for example (figured on p. 791), or in *Peziza aurantia* (see fig. 456⁷), it is easy to observe how small clouds of extruded spores rise from the surface of the fructification as soon as these Fungi are brought from a damp place into a dry atmosphere, or when a dry wind blows over them. In some species of *Ascobolus*, minute black or waxen yellow Fungi living on the excrement of animals, the spores are not only ejected, but the turgidity of the tissue surrounding the tubes is so great that the whole tubular layer is extruded with the spores.

Some Gasteromycetes have special contrivances for scattering the spores. In species of the genus *Geaster* (see figs. 391⁴ and 391⁵, p. 690) the threads of the capitulum and the spores imbedded between them develop within a tough, leathery, bladder-like envelope which separates into two layers when the spores are ripe. The inner layer has the form of a bladder, and opens only at a spot at the apex. The outer layer, on the other hand, splits into 4-12 radiating lobes. The position of the lobes alters remarkably according to the hygroscopic condition of the atmosphere. In damp weather they fold together over the vesicle, but in dry weather, especially in sunshine and when a dry wind is blowing, they bend back so forcibly that some of the spores are shaken from the mouth of the vesicle. Travellers in Central America tell us of the gigantic Puff-balls which literally explode on being

shaken, sending such quantities of reddish spores into the air that it is impossible to breathe in their vicinity. In Europe a minute Puff-ball, *Sphaerobolus stellatus* (fig. 456⁶), grows on decaying stems, leaves, &c. The wall of the fruit divides, as in *Geaster*, into two distinct layers: one remains closed and assumes the form of a ball, but the outer one when the spores are ripe divides by radiating clefts into several lobes. These bend back rapidly on drying, and as the central portion round which the lobes are placed becomes strongly arched upwards, at the same time the ball containing the spores is shot out with considerable force.

The dissemination of spores in some of the Ferns is illustrated in figs. 456^{3, 4, 5}. Sporangia are developed on the under surface of the frond, where they are arranged in various ways. Those of the *Nephrodium Filix-mas*, which is here selected as a type, consist of a stalk and a flattened bi-convex vesicle. Round the latter runs a ring of darker-coloured cells, whose side-walls are much thickened, while their outer walls remain thin and delicate. When the sporangium is ripe its bursting is brought about by the contraction of the cells of the ring.

With regard to the distribution of offshoots by animals we may distinguish two classes, those in which the offshoots are first conveyed to the animals by special disseminating mechanisms, so that two methods of distribution are combined, and, secondly, those in which animals alone effect the transport of the offshoots from one place to another. We have already spoken repeatedly of the former class. Of the latter the distribution of spores by food-seeking animals is the first to be considered. The Pyrenomycetous Fungus known as the Ergot of Rye (*Claviceps purpurea*) is a well-known instance. The thick web of hyphal threads which invests the ovaries of the Rye is penetrated by labyrinthine passages, whose walls are formed by the ends of hyphal threads arranged in rows and tufts (see fig. 386², p. 680). Spherical spores are abjoined from these somewhat club-shaped ends. Simultaneously with this abjunction the outer layer of the cell-wall of both spores and hyphæ forms a sugary fluid by the absorption of water and subsequent breaking down. This fills the winding passages, and the innumerable abjoined spores are imbedded in it. The sweet-tasting fluid gradually collects into drops on the exterior, and even comes into view on the spikes of Rye between the glumes which surround the infected ovaries. This is the "honeydew" by which the presence of the parasitic *Claviceps* in the interior of the spike is recognized, and which is viewed with some apprehension by the farmer. Insects, especially wasps and flies, eagerly seek out these springs of sweet fluid and suck and lick up the juice, which is crowded with numberless spores. It is therefore inevitable that small quantities of spores should stick and remain hanging to portions of their bodies, and when they fly to the spikes of other Rye-plants the spores are easily rubbed off, and in a very short time may again grow up into a mycelium involving the ovaries there.

A similar phenomenon may be observed in the Phalloidæ, belonging to the Gasteromycetes, of which the best known species, the Stink-horn Fungus (*Phallus impudicus*), may be taken as an example. The cap, borne on a white cylindrical and spongy stalk, is bell-shaped and covered with a greenish-black viscous fluid in

which numerous spores are imbedded. This fluid gives off a far-reaching carrion smell which allures many insects, especially carrion-flies. The fact that the fluid contains sugar which serves as nourishment for the insects also contributes to the allurements. A fly which alights on the cap of the Stink-horn cannot leave it without spores adhering to its whole body. Some of them may, perhaps, fall off while it is flying away, but the majority will not be brushed off until it again alights and cleanses itself from the uncomfortable appendages (*cf.* also p. 691).

It is well known that the fleshy fructifications of Hymenomycetes provide food for numerous insect-larvæ. Frequently as soon as the receptacles appear above the soil the flesh of the stalk and cap are riddled by passages in which live the larvæ of various gnats and beetles. These leave their dwellings before the decay and decomposition of the Fungi set in, and enter the chrysalis stage in the ground. In this way numerous spores which have adhered to the animals are carried away and disseminated. The spores of various Fungi, especially of the Hymenomycetes and Truffles, are without doubt distributed by animals which eat the fleshy spore-bearing portions. The spores pass unharmed through the alimentary canal and then germinate in the deposited excrement. Earthworms and swine in particular seem to take part in this distribution.

The dissemination of detached bud- and shoot-like offshoots is comparatively seldom effected by animals. Of the cases known the following are the most noteworthy. First, where the offshoots are taken up as food by animals, but are again got rid of in an undigested condition, and grow up into new plants in the place where they have been deposited. This has certainly been observed in *Polygonum viviparum*, which grows commonly in the far North and on the high mountains of Central Europe (see fig. 452). The bulbils of these plants are a dainty morsel to ptarmigan, and are eagerly sought for by them. The ptarmigan seizes the lower half of the spike of the *Polygonum* with its beak, and by a quick movement of its neck passes the bill the whole length of the spike, and so puts dozens of bulbils at a time into its crop. Numerous observations have shown that the bulbils of *Polygonum viviparum* and cranberries are the commonest food found in the crops of ptarmigan shot on the Alps, and I also always found these bulbils in great quantity in the crops of Norwegian ptarmigan. The portion which passes from the crop into the muscular gizzard is of course crushed and digested, but it has often been noticed that part of the food so greedily swallowed by the ptarmigan is thrown up again, and this is particularly the case with the bulbils when they have been taken in excess. When thus extruded, they have the power of further development; far from being destroyed, they grow up very rapidly into new plants, and as the places where the superfluous food is thrown out are always at some distance from the spot where the ptarmigan obtained the bulbils, this process is really a mode of distributing the *Polygonum viviparum*.

The second method of distributing detached offshoots by animals is effected by means of barbed bristles and hairs, such as are represented in fig. 457, in the Mamillarias (*Mamillaria placostigma* and *gracilis*) of the high mountains of Mexico.

Here some of the spherical, closely-crowded lateral shoots growing from the old plant loosen spontaneously and fall to the ground; others again remain *in situ* but adhere very slightly, so that a passing contact or a gentle touch is enough to complete the separation from the old plant. Now bristles are formed at the top of each papilla of these *Mammillarias*, some of which end in barbs, so that the spherical shoots resemble burs. They adhere just like burs to the hairy paws or fur of grazing animals, which carry them away unconsciously. Afterwards

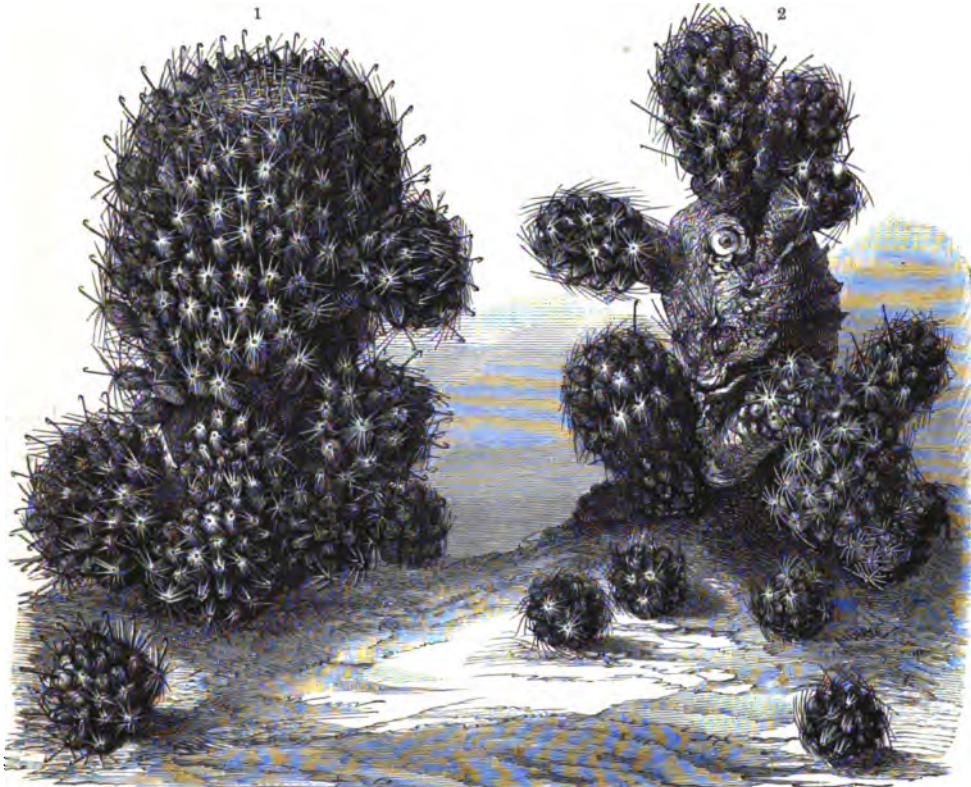


Fig. 457.—Distribution of detached sprout-like offshoots by means of animals.

1 *Mammillaria placostigma*. 2 *Mammillaria gracilis*.

the animals when resting seek to rid themselves of the inconvenient appendages, brushing them off and leaving them behind on the ground. Here they may strike root and grow up into new plants.

The third method of distribution of sprout-like offshoots by animals is seen in aquatic plants, which fasten either entirely or in fragments to passing water-birds. Certain species, which very rarely blossom or form fruit, but nevertheless occur in innumerable widely distant spots and often appear unexpectedly in newly-formed ponds, in artificial lakes, and in other waters, are for the most part distributed by water-birds. Some of these water-plants, *e.g.* the Frogbit and Bladderwort (*Hydrocharis* and *Utricularia*), develop peculiar slimy coverings round their buds, which

cause them to stick to the feathers of birds which come in contact with them as they swim by. Others, such as the small Duckweeds (*Lemna minor*, *gibba*, *polyrrhiza*), hang by their long, somewhat twisted, floating roots, and many filamentous Algæ, *Aldrovandia*, the delicate Riccias (*Riccia natans* and *fluitans*), the Ivy-leaved Duckweed (*Lemna trisulca*), &c., become attached in their entirety to the coot and duck swimming in the ponds and lakes. These fly away with them, but as soon as they again enter other water the adhering plants fall off or are cleaned off by the birds, and in this way they are distributed quite fresh and living over great distances. We might also mention in this connection the peculiar distribution of Ulvas, Floridææ, and Sea-wracks by means of crabs, which was described at vol. i. p. 77.

We will only allude in passing to the fact that many economic plants are propagated and distributed by offshoots to a very great extent by man. Bananas whose fruits contain no fertile seeds, Potatoes, Artichokes, and many other tuberous and bulbous plants are continually multiplied by the help of slips, tubers, bulbs, &c. The intentional artificial propagation by offshoots has of course no apparent influence on the development of a natural method of distribution in such species. Although planted and cultivated in large quantities they do not become naturalized; and if it were not for the artificial maintenance and propagation by offshoots they would soon vanish again from such places, leaving no trace behind. This is, however, not the case with the unintentional distribution of offshoots of certain plants by man. The keels and bottoms of ships journeying over wide seas become, like the stakes and buoys of the harbour and the sea-walls and rocks of the shore, quite overgrown with sea-weeds. If these are removed by chance or intentionally from their substratum they do not necessarily perish. They may remain alive in the seawater, and under favourable conditions may attach themselves to some other firm spot of ground. In this way plants may be transmitted from one coast to another over very wide distances. Another unintentional distribution of plant-offshoots by man occurs on cultivated ground in vineyards, fields, and gardens. By ploughing, digging, and throwing up the soil the bulbous or tuberous offshoots embedded in the ground undergo a change of position. The offshoots of certain plants may in this way be distributed so uniformly over a whole field by spade and ploughshare in the course of a year that it almost looks as if they had been purposely planted there. It is curious on journeying through the vine-planted districts of Northern Italy to see one of two adjacent vineyards abundantly covered with wild Tulips, while not one is visible in the other. In Central Europe the same thing happens with the Gageas (*Gagea arvensis*, *G. stenopetala*) growing in the fields, and with the tuber-forming Earth-nut pea (*Lathyrus tuberosus*). One field looks as if it had been sown with Gageas and yet its neighbour is completely devoid of them. On the Günselhöhe in the Lower Austrian Erlafthal I once saw a rectangular ploughed field overgrown from one end to the other with plants of the Bulbiferous Lily (*Lilium bulbiferum*), while only isolated specimens of this plant could be seen in the adjoining fields. There is no doubt that here the bulbils thrown on to the ground from the

leaf-axils of a few plants had been distributed equally by ploughing over the whole field, although this distribution had certainly not been intended by the ploughman,

It would of course be a mistake to explain the uniform distribution of bulbous plants over a large stretch of land exclusively by the ploughing and overturning of clods of soil full of bulb-like offshoots. In many instances the distribution of such offshoots is also produced by the pulling action of the roots. This process is so remarkable that we must describe it somewhat in detail. The multiplication of subterranean bulbs is known to take place by the formation of buds in the axils of the scale-leaves, and these, in the course of a few months, themselves grow up into small bulbs. When mature, they may form the termination of a slender shoot which, of course, never attains any considerable length, but which in many cases is thread-like, as shown in *Muscari racemosum* (fig. 444¹). The small bulbs are pushed by this thread-like shoot out of the region of the protecting scale-leaf near the old bulb, and there they develop long root-fibres in abundance. In other instances the shoots remain extremely short, and the small bulbs are not pushed out, but the protective scale-leaf, in whose axil they originated, decomposes, and they send out their roots through the decomposing tissue into the surrounding soil. In both cases they become detached at the end of the vegetative period in which they originated; they are then no longer connected with the old bulb, but are quite independent. Many species form only one bud in the axil of a bulb-scale, others a whole series which all grow up into bulbs; in the latter case the old bulb in the autumn is surrounded by a whole family of small young bulbs. There is a species of Garlic called *Allium pater-familias* whose old bulb gives rise to about a hundred young ones in a year. It is impossible for so many to develop properly when closely crowded together round the plant from which they sprang; mutual pressure would be unavoidable in their further growth, and if next year each of these bulbs should in its turn form new offshoots, and again become the centre of young bulbs, it would become imperatively necessary to make room, and to thin and separate the dense crowd. Since all the bulbs are placed with their apices pointing upwards they cannot be moved apart by the elongation of their stems; the mutual pressure of neighbouring bulbs as they enlarge would certainly cause a trifling displacement, but this would not prove an efficient remedy. The remarkable pull of the roots, which was described in vol. i. p. 768, now comes into play. Only a few of the roots arising from the base of a young bulb strike downwards; by far the greater number grow out at a right angle to the axis of the bulb in a direction parallel with the surface of the soil (see fig. 444¹). When these very long roots have stopped growing they contract, and thus draw the young bulb to which they belong away from the old one. The young bulbs now form a wide open wreath round the old one (which has meanwhile disintegrated), and thus obtain sufficient room for further development. This happens not only in the *Muscari* described, but also in *Ornithogalum nutans*, *Tulipa sylvestris*, and indeed in quite a number of bulbous plants. Since this process is repeated annually a fairly wide area of soil may in the course of years be covered with the bulbs in spite of the slight distance through

which they have been shifted under the ground. Some soil containing bulbs of *Tulipa sylvestris* was once put in a garden in Vienna in the middle of a grass plot shaded by Maple-trees. As the grass was mowed every year before the flowers opened there was no formation of seed, and the Tulips could only multiply by offshoots. After about 20 years the lawn was covered with Tulip-leaves, which arose from subterranean bulbs occupying an area 10 paces in diameter. Thus in the time mentioned the bulbs had spread for about 5 paces in all directions, in consequence of the pull of the contracting roots. It is more than probable that the offshoots of many perennial plants with erect stem and napiform or tuberous roots, e.g. the blue-flowered species of the Monkshood (*Aconitum Napellus*, *A. Neubergense*, *A. variegatum*) undergo a change of position by the pull of their horizontal root-fibres; and that the clustered arrangement of these plants is the result of the root-pull.

A review of the very varied modes of origin and distribution of offshoots leads to the conclusion that they may be formed on all parts of the plant, that the form of the offshoot is constant for each species, or, in other words, that the form of the individual parts of the offshoot in succeeding generations is repeated as exactly as the flowers and fruit, but that one and the same species may frequently form two or even three kinds of offshoots. The Fungus *Claviceps purpurea* develops spores which are distributed by honey-sucking insects, also the sclerotia known as "ergot", which are scattered from the dry spikes by the swaying movement of the stem, and thirdly, filamentous spores, which are extruded from asci, and distributed by wind. The Liverwort *Blasia pusilla*, develops thallidia in special flask-shaped receptacles on the surface of the thallus, and spores in the sporogonia. The form of the offshoot is always adapted to the season and to the distributive agents available where they are formed. In one case it is more suitable that the offshoots should be distributed slowly, and step by step, in another quickly and by bounds. In the spring it may be more advantageous if they are distributed by wind, by animals in the summer, and by self-scattering mechanisms in the autumn. Steppe-plants must develop different offshoots from those formed by plants living on the damp, shady floor of the forest. It is just as obvious that offshoots, which creep along, above, or under the ground without leaving the soil, must be equipped quite differently from those which are detached from their place of origin, and either roll along or are carried by wind, or have to travel long distances as the appendages of wandering animals. In the former, it is all-important that they should be able to overcome possible obstacles in the soil; in the latter, that they should not perish during their journey for lack of food and water. When separated from the soil they are greatly exposed to the danger of drying up, and even when they have settled somewhere, the supply of water they require for the formation of organs of attachment and absorption is by no means assured. Settlers of this kind must either be so organized that they can sustain a long-continued drought without injury, like the offshoots of the Mosses and the soredia of Lichens, or they must themselves bring with them the necessary water supply, and care must be taken

that this supply is not lost prematurely by evaporation. As a matter of fact, such detached offshoots, e.g. those of *Sempervivum*, *Sedum*, *Kleinia*, or *Mamillaria*, are not only provided with a special aqueous tissue, but also with a cuticle which is very effective in preventing excessive transpiration. All offshoots, when liberated from their place of origin, are also provided with the necessary reserves, i.e. constructive materials, so that immediately after settling, they can send out absorbent roots and green leaves of their own initiative, obtain a firm footing in their new locality, and extract nourishment from it. When the offshoots are distributed by water-currents, they require neither an aqueous tissue nor protection against drying up, and it may be due to this fact that detached offshoots are relatively more frequent in aquatic than in land plants and lithophytes.

THE DISPERSION OF SPECIES BY MEANS OF FRUITS AND SEEDS.

On the heights of the Kahlenberg, at Vienna, at the edge of the wood, grows an under-shrub which bears the name of *Dorycnium herbaceum*. It is one of the Papilionaceæ, and develops spherical one-seeded fruits, which ripen in October. I once collected from this plant several twigs laden with fruit, for the purpose of a comparative investigation on which I was engaged, and brought them home and laid them on my writing-table. Next day as I sat reading near the table, one of the seeds of the *Dorycnium* was suddenly jerked with great violence into my face. Shortly afterwards I saw a second, third, fourth, and ultimately about fifty seeds let fly from the small clusters of fruit, and each time I heard a peculiar sound which accompanied the bursting open of the fruits and ejection of the seeds. The rays of sunshine from the window had evidently heated and dried the fruits, and occasioned this surprising phenomenon. The incident reminded me of the following passage in Goethe's *Travels in Italy*:—"I had brought home several seed-capsules of *Acanthus mollis*, and put them away in an open box, when one night I heard a crackling noise, and immediately afterwards a sound like the impact of small bodies against the walls and ceiling. I could not understand it at first, but found afterwards that my pods had burst and scattered their seeds all over the place. The dryness of the room had caused the fruits to ripen in a few days to the requisite degree of elasticity."

The fruits of *Dorycnium* and *Acanthus* may be taken as types of a large group designated by the name of Sling-fruits. It is found that when these fruits are ripe, the tissue around the seeds becomes highly tense. The first result of the tension is that the tissue is rent at particular spots, and this rupture is followed by a sudden contraction of the segments, which double back and roll up, at the same time expelling the seeds resting upon them. Sometimes the rolled parts of the fruits, and, more rarely, the entire fruits themselves, are jerked off simultaneously with the seeds. There is the greatest variety in this respect, but all the contrivances for expelling seeds resemble one another in the fact that through their agency the seeds reach places beyond the range of the mother-plants.

In one class of expulsive fruits the high degree of tension which finally results in the disruption and rolling up of particular tissues is caused by a swelling up of the cell-membranes or by the turgidity of the cells. One of the most curious instances is that of the Squirting Cucumber (*Ecballium Elaterium*), which is shown in fig. 458¹. This plant belongs to the Cucurbitaceæ and its fruit resembles a small fleshy cucumber beset with bristles and borne by a hooked stalk. The end of the stalk projects into the interior of the fruit like a stopper. When the seeds are quite



Fig. 458.—Sling-fruits.

¹ *Ecballium Elaterium*; branch bearing flowers and fruits. ² A fruit detached from its stalk and with its seeds squirting out. ³ *Oxalis Acetosella*; entire plant with one unripe fruit on a hooked stalk, and one ripe fruit on an erect stalk ejecting its seeds; nat. size. ⁴ Unripe fruit of *Oxalis Acetosella*; $\times 6$. ⁵ Ripe fruit of *Oxalis Acetosella* ejecting the seeds; $\times 6$.

ripe the tissue surrounding them is transformed into a mucilaginous mass. Also the tissue in the neighbourhood of the conical stopper just referred to breaks down at the same time, and thus the connection between the stalk and the fruit is loosened. In the wall of the fruit there is a layer of cells which is under great tension, and endeavours to stretch itself out. As long as the fruit is unripe such expansion is prevented by the tense tissue close to the stalk, but with the ripening of the fruit this obstacle is removed. The fruit then severs itself from the conical end of the stalk and at the same moment the expansion of the strained layer of tissue takes place. The consequence is that the interior of the fruit is subjected to great pressure, and the seeds, together with the surrounding mucilage, are squirted out

with considerable force through the hole which was previously closed by the end of the stalk (see fig. 458²).

The *Dorsteniaceæ* behave in a manner no less remarkable. As in the case of Figs so also in these plants, numbers of small flowers are seated upon an enlarged receptacle, which remains fleshy and succulent after the small one-seeded fruits have developed from the flowers. The lower portion of each fruit has thick walls, and is embedded in the receptacle like a hair-follicle in the human skin, whilst the delicate-



Fig. 459.—Sling-fruits.

1 *Orobus vernus*. 2 and 3 *Geranium palustre*. 4 *Viola elatior*. 5 *Cardamine impatiens*. 6 *Impatiens Nolitangere*. 7 and 8 *Acanthus mollis*. 9 and 10 *Ricinus communis*.

coated portion projects above the receptacle in the form of a papilla. When the seed is quite ripe the turgidity of the outer cellular layer of the thick wall of the fruit increases, the thin-walled top is torn, the thick walls suddenly close, and the seed hitherto enveloped by them is violently ejected.

A special case of the expulsion of seeds as from a sling is also found in *Oxalidaceæ*, of which the common Wood-sorrel (*Oxalis Acetosella*, see figs. 458^{3, 4, 5}) may be taken as an example. In this case it is the seed-coat that possesses a special tumescent tissue adapted to the expulsion of the seeds. One of the deeper layers of the seed-coat is composed of tense cells and is itself in a highly strained condition,

whilst the outer layers of cells of the seed-coat are not in a state of tension. When the seed is quite ripe the cell-membranes in the strained layer of tissue swell up, the outer layer of the seed-coat, being no longer able to withstand the pressure to which it is subjected, is rent asunder and the edges of the slit thus formed roll suddenly back. A violent jerk is given to the inclosed seed, in consequence of which it flies out through the fissure in the capsule immediately in front of it (fig. 458⁵). The fact of the ejection of the seeds of *Balsamaceæ* also has long been known. The fruit of *Impatiens Nolitangere*, one of the members of that family, is an oblong capsule composed of five carpels (see fig. 459⁶). The walls of this capsule are constructed of three layers of cells. The layer lying immediately beneath the epidermis consists of large and highly turgid cells, and is called the turgescens layer. It is in a state of great tension, and when the seeds are ripe and the union between the five carpels gives way along the lines of union, a relaxation of the tension takes place, the loosened tissue of those lines is torn, the five carpels roll up, and their rapid movements of involution result in the expulsion of the seeds contained in the fruit. *Cyclanthera explodens* and *Thladiantha dubia*, plants belonging to the *Cucurbitaceæ*, as also several *Crucifers* of the genera *Dentaria* and *Cardamine*, in particular the species shown in fig. 459⁵ (*Cardamine impatiens*), exhibit similar phenomena, except that in these cases the carpels do not roll inwards but outwards.

In the instances hitherto dealt with the cause of the expulsion is the turgidity of cells or the swelling up of cell-membranes with a concomitant maintenance of a state of extreme tension in a particular layer of tissue situated in the wall of the fruit. In the next class of cases the phenomenon depends on the desiccation and consequent contraction of a special layer of the fruit-wall which leads to a rupture and subsequently to a bending over and rolling up of particular parts of the fruit. This change is accomplished with great rapidity and has the effect of hurling away the seeds or the separate parts of the fruit or even the entire fruit itself. We will only mention some of the best known instances of this kind.

The fruit of the Marsh Crane's-bill (*Geranium palustre*; see fig. 459³) has a 5-angled column rising up in the centre of a circle of five carpels. The carpels are hemispherically inflated at the base, and terminate above in long bristles or beaks. Each contains a single seed. When the seeds are ripe, the tissue composing the beaks undergoes desiccation, which, however, is not of uniform intensity throughout. The outer layer, consisting of several plates of succulent cells, dries up more quickly than the inner layer, which is composed of thick-walled cells. The result is that the beak lifts itself away from the axial column, and curls up externally like a watch-spring. No resistance to this movement is afforded by the delicate dried tissue which has hitherto served to hold the carpels together, and as the cavity of each carpel is open along the inner surface, and the seed lies in it simply as though it were resting in the hollow of a hand, the rapid drawing up of the beak has the effect of ejecting it in a wide curve away from the carpel (see fig. 459³). In the Marsh Crane's-bill, as also in the other large-flowered species of the genus *Geranium*, the tops of the beaks continue attached to the axis, and the latter, together with the five

empty and rolled-up carpels, resembles a chandelier in shape (shown to right of fig. 459³).

Those Violets which have aërial stems, such as *Viola elatior* (see fig. 459⁴), develop capsular fruits, each of which resolves itself into three valves when it bursts open. The valves are boat-shaped, and the marginal parts which form the sides of the boats are thin, whilst the keels are very thick and swollen. Inside each boat, near and parallel to the line of the keel, are two rows of seeds. The valves themselves have an exceedingly complex structure. A cross section through one of them shows a layer of thin-walled parenchymatous cells, a layer of elongated curvilinear cells, and a layer of broad, greatly thickened cells. The unequal desiccation of these layers is the cause of the curving up of the lateral walls of the valves, which at last approach so near to one another as to exercise considerable pressure on the seeds in the middle. The result of this pressure is that the smooth seeds are shot out with about the same force as is imparted to a cherry-stone when it is flicked to a distance by the finger and thumb. The seeds are ejected in regular succession. The foremost seed of the first carpel goes first, and the seeds at the opposite extremity are discharged last. It is not till the first carpel is quite empty that the second begins to part with its seeds, and the third only comes into play when the second is finished. The drawing together of the two sides of the valve always begins at the free extremity of the valve, and lasts until all the seeds have been ejected.

In many Mimoseæ, Cæsalpinæ, Papilionacæ, Sterculiaceæ, and Acanthaceæ the seeds are expelled by means of a spiral torsion of the valves of the fruit at the moment that the legume or capsule opens. The wall of the fruit of these plants includes a soft succulent layer of thin-walled parenchymatous cells, and a hard layer of strongly-thickened elongated cells, which run obliquely from one edge to the other in each valve. The rupture of the fruit, and the spiral torsion of its valves at the moment of their separation, depend upon these diagonal cells of the hard layer. Each one of these cells winds itself into a spiral as it dries, and consequently the entire layer undergoes a corresponding torsion. The tissues composed of thin-walled cells, which are in connection with the hard layer, offer no resistance to the movement, and the rotation is therefore so sudden and violent that the seeds contained in the pod are projected to a distance. If the fruit is short, the valvular torsion is confined to $\frac{1}{2}$ –1 twists; if long, the spiral includes 2 or even 3 complete coils, and the valves of the empty fruit are curled up like ringlets (e.g. *Lotus corniculatus*, see p. 431, fig. 325³, and *Orobis vernus*, see fig. 459¹). The force of projection varies according to the thickness of the hard layer. In *Castanospermum australe*, where the pod-valves attain to a thickness of 5 millimetres, the sudden torsion causes the expulsion of spherical seeds, measuring 3·5 centimetres in diameter, and weighing 16 grams. In these cases the valves of the fruit persist upon the fruit-stalks after the ejection of the seeds, and herein lies the essential difference between them and those expulsive fruits of which the carpels break away from the stalks with the seeds. To this class of expulsive fruits belong also several Papilionacæ, such as the *Dorycnium* mentioned at the beginning of this section, and besides them the genus

Kitaibelia of the family Malvaceæ, *Alstroemeria* amongst the Liliaceæ, several Acanthaceæ, including the *Acanthus mollis* (see figs. 459⁷ and 459⁸), which Goethe has made familiar to us, the wonderful parasite, *Lathræa clandestina*, and many Euphorbiaceæ (e.g. *Euphorbia*, *Hura*, *Hyænanthe*, *Mercurialis*, *Ricinus*, see figs. 459⁹ and 459¹⁰). In all these plants the fruit-valves are comparatively short, and the spiral torsion is therefore less clearly manifested. The impulse given to the seeds by the twisting of the valves is supplemented by various other contrivances which cannot here be described, and, as a matter of fact, the range of projection in this group of sling-fruits is wide as compared with that of others.

A peculiar form of sling-fruit is found in several of the Diosmaceæ, Rutaceæ, and Zygophyllaceæ. In these plants a complete separation of the hard from the soft layer takes place. When the seeds are ripe the external soft layer dries, splits along the ventral suture, and contracts strongly. In consequence of this contraction the hard internal layer, which is in the form of a case inclosing the seeds, is forced out of the slit. As soon as the hard case is thus set at liberty its two lateral walls part asunder, assume the shape of the screw of a steamer, and eject the seeds to a distance. Similar processes occur in the genus *Collomia* of the family Polemoniaceæ, but in this instance it is not the soft outer layer of the valves but the calyx, which, on drying, exercises pressure on the inclosed case, and the latter, which is extruded, is not the hard layer only but the entire dry capsule. The liberation of the case is here materially assisted by the circumstance that the three valves of the capsule disunite at a time when they are still surrounded by the calyx, and hence exert a counter-pressure upon the calyx. When once the capsule is freed from the grasp of the calyx, its valves diverge still more widely from one another and eject their seeds. In *Eschscholtzia* also the entire fruit is jerked off the receptacle, but here the phenomenon depends on the fact that the two valves of the siliquose fruit attain to a high degree of tension on desiccation and tend to curve outwards. When the tension has reached a sufficient pitch to sever the connection between the fruit-valves and the receptacle, the whole fruit is shot away from the stalk in a curve. In the Stork's-bill (*Erodium*, see vol. i. p. 619, figs. 147³ and 147⁴), and in several Umbellifers (e.g. *Scandix*), the entire fruit is not thrown off, but the constituent parts of the fruit with their tightly inclosed seeds are jerked away from the central axis.

This cursory survey is sufficient to give an idea of the great variety existing amongst the sling type of fruit. Of course the fruits in question are always placed in such a position as to render a free flight of the seeds possible. In every case where the fruits before ejecting their seeds or being themselves jerked away are for any reason hidden under foliage-leaves, or are borne by stalks which bend downwards, as in the Wood-sorrel and the Violet (see figs. 458³ and 458⁴), the stalks straighten out just before expulsion takes place and lift the fruits up above the leaves. In most instances the angle of projection is 45°, and, as is well known, the greatest range of flight is thus attained. The ejected seeds are spherical, oval, bean-shaped, or lenticular. In the last case they are expelled in such a manner as

to cut edgewise through the air, and it is the invariable rule for seeds to be so ejected as to encounter as slight a resistance from the air as possible whatever their shape may be. Contrivances for determining the direction in which the expelled body is to move are rare. A first indication of some such adaptation occurs in the Wood-sorrel (see fig. 458⁸) and in *Ricinus* (see fig. 459¹⁰), where the seeds are thrust through an opening of definite shape. In the Acanthaceæ (*Justicia*, *Acanthus*, &c.), the path of projection is determined by the circumstance of the seeds resting before their expulsion against rigid curved bars springing from the partition-wall which runs through the fruit (see fig. 459⁸). The act of expulsion is usually accompanied by a characteristic noise like that of the bursting of a bladder, and the sound amounts to a regular detonation in the case of the dehiscence of the fruits of *Hura crepitans*. The range of projection is least when the seeds are small and light, and greatest when they are large and heavy, as is shown by the following table:—

Name of Plant.	Shape of Seed.	Longest Diameter of Seed in Millimetres.	Shortest Diameter of Seed in Millimetres.	Weight of Seed in Grams.	Range of Projection in Metres.
<i>Cardamine impatiens</i>	ellipsoidal	1·5	0·7	0·005	0·9
<i>Viola canina</i>	oval	1·8	1·0	0·008	1·0
<i>Dorycnium decumbens</i>	spherical	1·5	1·5	0·003	1·0
<i>Geranium columbinum</i>	spherical	2·0	2·0	0·004	1·5
<i>Geranium palustre</i>	cylindrical	3·0	1·5	0·005	2·5
<i>Lupinus digitatus</i>	cubical	7·0	7·0	0·08	7·0
<i>Acanthus mollis</i>	bean-shaped	14·0	10·0	0·4	9·5
<i>Hura crepitans</i>	lenticular	20·0	17·0	0·7	14·0
<i>Bauhinia purpurea</i>	lenticular	30·0	18·0	2·5	15·0

It will be noticed that as a means of distribution the agency of expulsive fruits is confined to a very restricted range. As compared with the distances to which seeds are conveyed by other means, such as the wind, the range of projection of the most powerful contrivances for expulsion, viz. 15·0 metres, is inappreciably small. This may account for the facts, firstly, that expulsive fruits are produced by comparatively few plants; and secondly, that such plants as do possess them are for the most part denizens of localities that are sheltered from the wind, where, therefore, the conditions are not favourable to dispersion by that agency. *Cardamine impatiens*, *Dentaria*, *Impatiens*, *Lathræa clandestina*, *Mercurialis perennis*, *Orobis vernus*, *Oxalis Acetosella*, *Viola canina*, and *V. sylvatica* all inhabit retired and shaded woodlands, whilst others, as, for instance, *Geranium palustre* and *Lathyrus sylvestris*, climb over bushes and hedges on the borders of woods. Mention must also be made of the fact that in many cases a second mode of dispersing fruits and seeds acts conjointly with that of expulsion, as is indicated by the name of *Impatiens Nolitangere*, i.e. "Touch me not". Those sling-fruits, for instance, in which the high degree of tension is due to the swelling up and turgidity of particular layers of cells, are so constructed that the slightest touch on the outside causes a relaxation of the tension and the ejection of the seeds in the direction of the object that has touched the fruit. The animals which frequent the shady woods

where *Impatiens*, *Cardamine*, *Dentaria*, *Oxalis*, &c., grow, brush against the fruits of those plants in the course of their wanderings, and at once receive a charge of seeds, some of which are sure to be left sticking to the creature's fur or feathers. It has long been known that when animals pass over places that are overgrown by *Elaterium* (see fig. 458¹) and brush against its fruits, which hang down from hook-shaped stalks, they are bespattered with the mucilaginous mass in which the expelled seeds are embedded, and that as soon as they reach a place of rest they endeavour to get rid of the unpleasant encumbrance.

Several contrivances for the distribution of fruits and seeds remain to be described which, so far as regards their results, exhibit the greatest resemblance to the above sling-fruits, although the causes which determine the phenomenon in their case are utterly different. In the last-named the forcible expulsion is due to cellular turgescence, or to movements brought about by the drying up of hygroscopic cell-layers; in the cases now to be described the result depends solely on the elasticity of stems and fruit-stalks. The stems and stalks in question are strongly resilient, and are strained and curved by a force acting from without. The moment the force ceases to act, their quality of resilience causes them to return to their former position, and in doing so they jerk the fruits and seeds borne by them to a distance. Of these contrivances, which are called ballistic means of dispersion of fruits and seeds owing to their analogy to catapults or balistas, we will here deal with five forms. The simplest occurs in the *Compositæ*, whose fruit-capitula are borne upon erect, comparatively long, elastic, flexible stems. The small fruits of the capitulum are already detached from their short pedicels by the time they are ripe and are deposited upon the central disc of the receptacle, which is surrounded by involucreal scales, or at the bottom of the basket-shaped fruit-capitulum into which the floral-capitulum develops. They are so deeply bedded in this situation that it is not possible for them to fall out unless subjected to some external impetus. But the erect resilient stem which bears the capitulum has only to be bent to one side by a gust of wind or by the touch of an animal for the fruits lying on the fruit-capitulum (which is flat or excavated as the case may be) to be shot off by the recoil which ensues. In many of the *Compositæ* the involucreal scales which form the enveloping basket bend towards one another at the top so as to constitute a roof; they are, however, elastic and flexible and very smooth on the inner surface, so that the fruits when ejected easily slip by them, and yet are to a certain extent guided in the course they take by the tips of the scales. In other *Compositæ*, of which the genus *Telekia* is an example, the floral receptacle is thickly clothed with so-called paleæ, and the fruits to be ejected, which, it may be noted incidentally, have no pappus, are embedded amongst these paleæ. The paleæ are erect and stiff, and are edged with small, upturned teeth; the slightest shock sends the fruits a little higher up amongst the scales, and they cannot then return to their former position, as the stiff marginal teeth bar the way. The fruits thus seem to make their way up the scales, step by step, as though they were ladders. If, when they have nearly reached the top, there comes a gust of wind which sets the peduncles of the capitula

rocking to and fro, the fruits are thrown out from between the elastic tips of the scales and describe an open curve before they reach the ground. A third group of Composites, which may be represented by *Centaurea Pseudophrygia* and *C. stenolepis*, exhibits the following arrangement: The receptacle is destitute of paleæ, but the involucreal scales form a sort of basket at the bottom of which are the fruits. In damp weather the tips of the bract-scales close tightly together, and the short bristles of the pappus crowning each fruit are applied closely to one another. In warm, dry weather especially, under the influence of a dry wind and sunshine, the scales part asunder and the basket stands wide open. At the same time the hairs

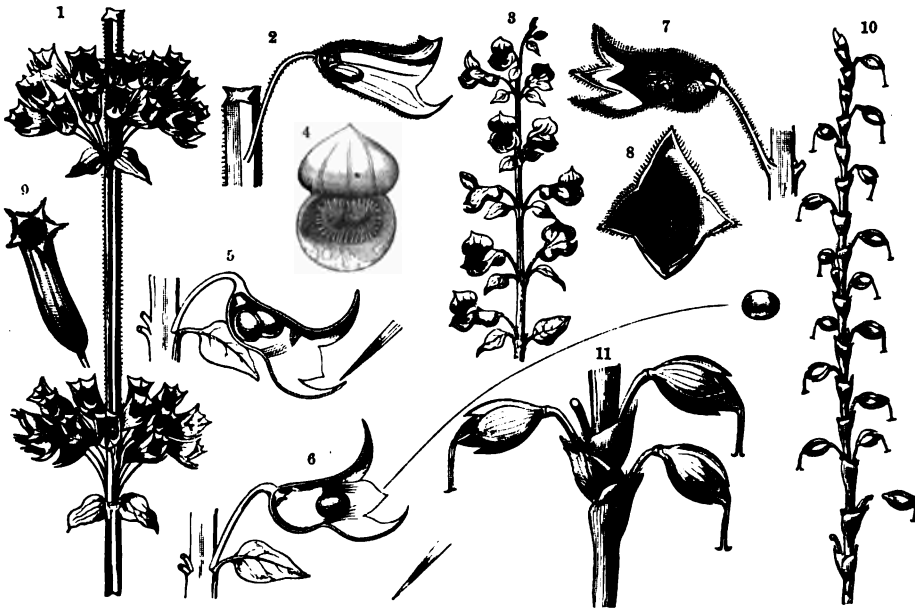


Fig. 460.—Catapult fruits.

1 and 2 *Salvia verticillata*. 3, 4, 5 and 6 *Teucrium Eganæum*. 7 and 8 *Teucrium flavum*. 9 *Monarda fistulosa*. 10 and 11 *Polygonum Virginicum*. 1, 2 and 10 nat. size; the others magnified.

of the pappus bristle up, and in so doing raise the fruits to the open mouth of the basket. If the peduncle supporting the capitulum is now set in motion, the fruits are tossed out like shuttle-cocks. The bristly pappus-hairs are not in this case organs of flight; they are short and stiff, and, besides raising the fruits, serve also to determine the direction of their fall. Balistic apparatus very similar to that just described is also found in several *Iridaceæ*, *Liliaceæ*, *Caryophyllaceæ*, *Primulaceæ*, and *Scrophulariaceæ*, only in them the erect, resilient stem does not bear a fruit-capitulum but a capsule, and the ejected particles are not fruits but seeds. The seeds are comparatively large and heavy, and are destitute of membranous or hairy appendages. In all these cases the capsule is situated with its orifice upwards and only opens in dry weather. As its cavity is very deep, no ejection of the seeds ensues except when the resilient stalk which carries it sways somewhat violently to and fro.

The manner in which the fruits of Labiatae are thrown off is particularly remarkable. The fruits in question are spherical, oval, or ellipsoidal nutlets, and when ripe are still hidden at the bottom of the persistent calyx. The calyx is either bell-shaped or tubular, and faces laterally; the pedicel supporting it is resilient, and usually bowed (see figs. 460^{1, 2, 3, 6}). If one presses upon the stiff points of the calyx with some hard object such as a piece of wood (fig. 460⁵) the pedicel is subjected to a strain, and as soon as the pressure ceases it springs back to its former position, and the nutlets are shot out with great force (fig. 460⁶). The path of projection is in this case determined by the two inferior calyx-teeth, which curve upwards like sledge-runners (see fig. 460²). In many instances, as, for example, in *Teucrium flavum*, *T. Euganeanum*, and *Monarda fistulosa* (see figs. 460^{3, 4, 5, 6, 7, 8, 9}), there is yet another contrivance for ensuring the proper direction of flight. This consists in the presence of stiff though pliable convergent hairs in the calyx-tube, and their function may be compared to that of the grooves in a rifle. Again, in *Scutellaria* the lobes of the calyx-limb, which is in the form of a tilting helmet with the visor down, determine the path of the seeds after expulsion. The result thus artificially attained by bending down the stalks of the fruiting calyces and letting them fly up again is brought about in nature by gusts of wind, by drops of rain, and most frequently of all by animals brushing against the calyces. In the last-mentioned event one or other of the ejected nutlets may stick to the animal's coat and be carried to a much greater distance than would otherwise be the case. This kind of apparatus rarely occurs in plants other than Labiatae. The nearest analogy is found in the ejection of seeds from the fruits of several species of the Chickweed genus, e.g. *Cerastium macrocarpum* (see p. 448, fig. 340⁴), where the fruits are curved like the letter S, are borne on stiff stalks and hold the ends that open upwards.

One of the most curious forms of mechanism of the catapult variety occurs in the North American *Polygonum Virginicum* (see figs. 460¹⁰ and 460¹¹). In this plant the fruits are on short stalks, and are arranged in spikes on long switch-like stems. The fruit-stalks are remarkable for the fact that the cells of the cortical parenchyma, which is greatly developed, have their walls strongly lignified, though only slightly thickened. It is also noteworthy that between the stalk and the fruit there is a layer of separation which looks like a joint to the naked eye. The style is transformed into a decurved beak, which is seated upon the fruit, and terminates in two little divergent hooks. When one of these fruits is pushed by a passing animal it is at once detached at the separation-layer and springs away to a distance. The pressure applied to the fruit is apparently transmitted to the short stalk, and gives rise to a condition of tension in the tissue of the stalk analogous to that of a watch-spring. As soon as the pressure ceases the tension relaxes, and the fruit is cast away with great force. For a long time it remained a mystery how these fruits were thrown off in the absence of any animals to give the initial impulse. A few years ago, however, I succeeded in observing the manner in which the long fruiting switches are swayed backwards and forwards by a boisterous wind,

and how they brush against one another and against the branches of neighbouring shrubs as they swing, and thus receive the stimulus necessary to cause them to throw off the fruits. The contact of animals is, however, a more advantageous means of dispersion, inasmuch as the fruits may be left hanging to their coats by the hard styles and the range of distribution be greatly increased thereby. When there is no assistance from animals, and the cast-off fruits simply fall to the ground, the range of projection is not more than 2-3 metres, which is a comparatively small distance from the spot where the fruits were ripened.

The limitation of the range of dispersion is still more marked in the case of fruits which creep or hop along the ground than in those where the action is that of a sling or of a catapult. The fruits in question have stiff and very hygroscopic bristles projecting on one side from their external coats, and these bristles continually change their position according to the varying state of the environment in respect

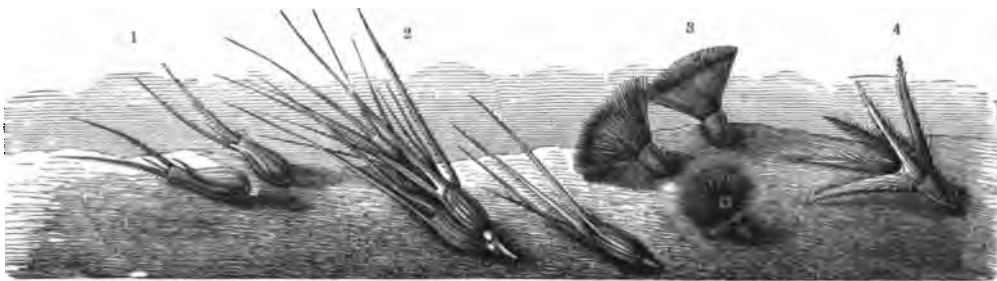


Fig. 461.—Creeping and hopping fruits.

¹ *Egilops ventricosa*. ² *Egilops ovata*. ³ *Crupina vulgaris*. ⁴ *Trifolium stellatum*

of moisture, and by so doing propel the fruit or seeds, as the case may be, in a definite direction. The awns which project from the glumes of Grasses (e.g. *Elymus crinitus*, *Secale fragile*, and various species of *Egilops*; see figs. 461¹ and 461²), the strong bristles in which the bract-scales of the flowers in Restiaceæ terminate (e.g. the South African plant, *Hypodiscus aristatus*), the calyx-bristles and stiff pappus-hairs in Scabiousses and Composites (e.g. *Crupina vulgaris*, see fig. 461³), and the divergent calyx-teeth in Papilionaceæ (e.g. *Trifolium stellatum*, see fig. 461⁴) constitute structures whereof the different parts alternately approach and recede from one another and so cause a movement resembling that of creeping. In all these cases the hygroscopic structures are furnished with small teeth. Sometimes the teeth are on both sides, sometimes on one side, and sometimes only at the tip (see figs. 462^{1, 2, 3, 4}). The teeth render retrogression impossible, and to that extent determine the direction in which the fruit moves. In *Avena elatior*, *Avena pratensis*, and several other Grasses the awns which project from the base of the enveloping glumes are bent elbow-wise. The part below the bend is spirally twisted, and as the tissue is extraordinarily hygroscopic, the spiral relaxes or contracts according to the amount of moisture in the air. This spiral motion causes the part of the awn which is above the bend to move like the hand of a watch, but now to one side, now to the other. Of course this movement can only

take place provided the part of the awn which undergoes it is not fixed down anywhere by an obstacle. If one of the lever-arms of the awn encounters a fixed object on the ground the spiral motion of the lower arm sometimes has the effect of forcing the tip of the awn over the obstacle, so that the whole structure shoots obliquely upwards. This phenomenon is especially conspicuous in *Avena sterilis*. In this case two glumes furnished with strong bent awns are to be seen on the fruiting spikelet after it has fallen. An alteration in the environment in respect of moisture causes the two awns to twist in opposite directions, so as to cross one another. After pressing one upon the other, they ultimately slip apart with a sudden jerk, which causes the whole fruit to spring up. This movement is much more like hopping or jumping than creeping.¹

The distance traversed by creeping, hopping, and bounding fruits is seldom greater than a few decimetres. The movements generally land the fruits almost

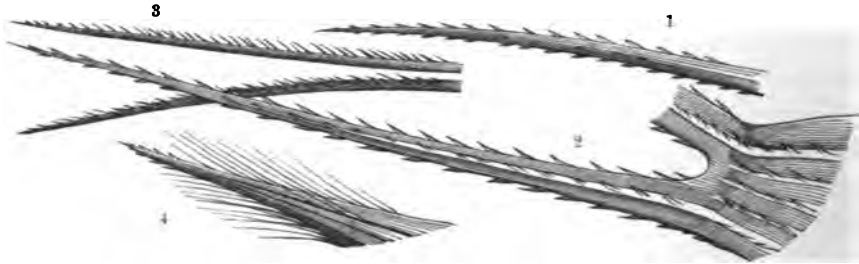


Fig. 462.—Fruits which creep or hop along the ground.

¹ Awn of *Egilops ventricosa*. ² Awn of *Egilops ovata*. ³ Bristles of the pappus of *Crupina vulgaris*. ⁴ Calyx-tooth of *Trifolium stellatum*; all the figures magnified.

immediately in some *cul de sac*, where they remain, or else the awns gets entangled with the above-ground stems and leaves, and in that case the result of the movements is to imbed the seeds, which are concealed in the fruit-scales, in the earth (see vol. i. p. 617). In such cases no doubt the most important function of the movements in question is to fix the plants in the soil, but on the other hand it cannot be denied that a limited form of dispersion may be and is as a fact achieved by these movements.

The dispersion of fruits through the agency of water takes place in all plants which undergo fertilization under water and detach their fruits when they are quite ripe. To this class of fruits belong the Fungi of the family *Saprolegniaceæ*, and most of those Cryptogams which are known as Algæ. Such facts as have been ascertained by botanists concerning the distribution of the fruits of these plants in the water have been recorded in previous pages (see pp. 49 and 64). This method of dispersion is of less importance in the case of Phanerogams, which are fertilized and ripen their fruits in the medium of the air. At first sight one might

¹ The hopping movements of the fruits of the Mexican plant named *Sebastiania Pavoniana*, and of those of *Tamarix Gallica*, which belongs to the Mediterranean floral area, are not due to alterations in the tension of particular parts of the fruit-coat, but are caused by insect-larvæ which live inside the fruits. In the case of the "Mexican Jumping Bean", the larvæ are those of the small lepidopterous insect named *Carpocapsa saltitans*, and in *Tamarix Gallica* those of the beetle *Nanodes Tamarisci*.

suppose that rain-water running off the plants and then trickling along the ground would be a very effectual means of dispersing fruits and seeds, but closer observation convinces one that distribution is comparatively seldom effected in this manner, and that wherever such dispersion does occur it is invariably supplemented by some other means of dissemination. The best-known instances are afforded by two plants which, on account of their extraordinary properties, were brought to Europe from the East by pilgrims and crusaders in the Middle Ages. They were called "Roses of Jericho", and all sorts of marvellous tales were told concerning them. One of these plants is *Anastatica Hierochuntica*, a Crucifer which grows on the Steppe-lands of Egypt, Arabia, and Syria, and which has the peculiarity that its branches

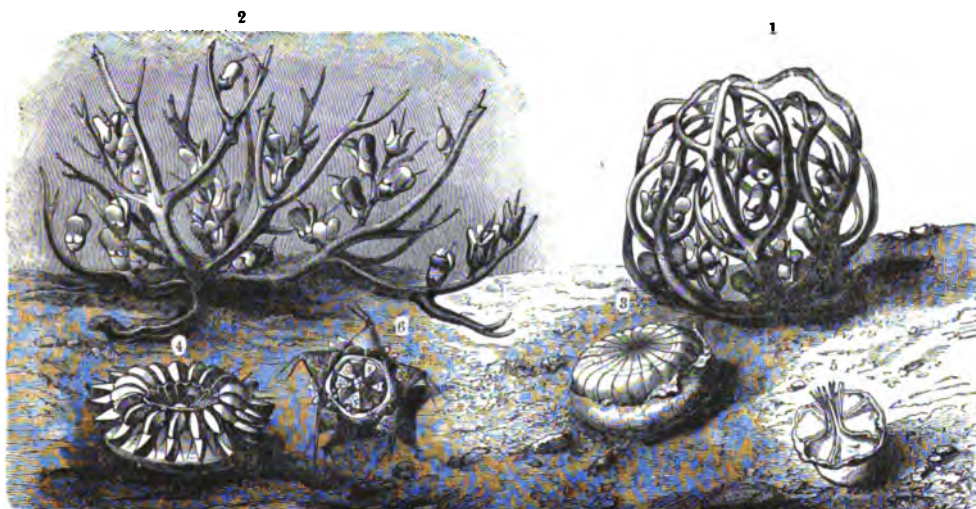


Fig. 468.—Fruits which open upon being wetted with water.

¹ *Anastatica Hierochuntica*, dry. ² The same when wetted. ³ Fruit of *Mesembryanthemum Candolleianum*, dry. ⁴ The same when wetted. ⁵ Fruit of *Mesembryanthemum annuum*, dry. ⁶ The same after being wetted.

curve inwards when the fruits are ripe in such a manner as to form a trellis round the closed, pear-shaped siliquas, which are very numerous and are situated at the extremities of the ramifications, and to protect them from being touched (see fig. 463¹). The shape of the structure in this condition is something like that of an unopened rose, and it remains unaltered so long as it keeps dry. When moistened the branches at once open back and stretch straight out (see fig. 463²). The fruits also open at the same time, and the seeds are then liable to be washed out of the fruit-valves by falling rain. When growing wild *Anastatica* remains closed during the long drought which follows the maturation of the fruits, and it is not till the winter rains set in that the tangle of branches opens and the seeds are washed out of the fruits. The second "Rose of Jericho", *Asteriscus pygmaeus*, is a small plant of the Composite family, and ranges from the northern portion of the Sahara to Palestine, being met with in especial abundance in the neighbourhood of Jericho. In this case the branches do not close together when the fruits arrive at maturity, but the involucreal leaves, which are arranged in a rosette, close up over the capitula

of fruit and do not open until the winter rains set in and cause the "rose" to unfold, whereupon the fruits are washed away.

Similar phenomena in connection with the rainfall are exhibited by the fruits and seeds of the so-called Ice-plants (*Mesembryanthemum*) which occur in a great variety of forms at the Cape. The capsular fruits of these plants remain closed in dry weather; but the moment they are moistened the valves covering the ventral sutures of the fruit-loculi open back, dehiscence takes place along the ventral sutures, and the seeds, hitherto retained in a double shroud, are washed out of the loculi by the rain (see figs. 463^{3, 4, 5, 6}). Amongst plants belonging to the flora of Europe, the Yellow Stone-crop (*Sedum acre*) responds to the influence of rain in a manner which reminds one strongly of the Ice-plants above referred to. The carpels are arranged radially, and are furnished at the base with wing-like borders, whilst the central part of the external surface of the fruit is in the form of a shallow basin. In dry weather the five fruit-loculi are closed; but the moment a drop of rain falls upon the concave centre they open wide, and the next few drops wash out the seeds, which are of small size, and convey them to the ground. As the rain trickles into the tiniest crevices in rocks and walls, the seeds are carried into holes in vertical or even overhanging cliffs where it would be scarcely possible for them to be deposited by any other means of dispersion. In the case of *Veronica Cymbalaria*, which grows on walls in the south of Europe, the fruits likewise remain closed so long as the weather is dry and only open when they are thoroughly soaked. The seeds are then carried, like those of the Stone-crop, into the holes and crevices of vertical walls by means of the infiltration of rain. Similarly in the cases of *Veronica agrestis* and *Veronica serpyllifolia*, species of Speedwell which grow profusely on cultivated ground, the seeds are washed out of the gaping capsules by rain and conveyed to spots where they find conditions favourable to germination. It is worthy of note that the capsules of *Veronica Anagallis*, *V. Beccabunga*, and *V. scutellata*, species which grow on banks and in running water, also do not open until they are thoroughly wetted by rain. The explanation of this curious fact must be as follows. If the wind were to act as the means of dispersion there would be a risk of the seeds being deposited on dry places where they would be doomed to perish. On the other hand, the rain carries the seeds on to the wet soil of the marsh or into the shallow water of the brook or pond, as the case may be, where the plant in question finds favourable conditions.

I must again repeat that actual contrivances with a view to seeds being washed out of open fruits by rain are comparatively rare. This, of course, does not exclude the possibility of fruits or seeds unprovided with such contrivances being dispersed by rain, or by the little tributaries of rivulets, which result from showers of rain if once they are transferred by any means into the channels in question. The rills of water which run swiftly down to join larger streams after a violent fall of rain collect not only sand and earth, but also any seeds that may have been deposited on the ground by the wind, and they subsequently set them down with the mud at the edge of the stream. Those fruits and seeds also which fall by chance into running

water, during transportation by aerial currents, may be floated along, and finally deposited by the stream. Numbers of fruits and seeds of the most various kinds of plants are invariably found to have been deposited on the banks of sand by the sides of mountain-torrents, and on the margins of rivers and rivulets after the water has subsided from a state of flood. Many of them, it is true, have no chance of developing, but perish, either because the conditions are unfavourable, or because they have lost their capacity for germination in the transit; others do, however, germinate, and some even thrive luxuriantly. But such seeds can only be said to have been accidentally dispersed by running water, and must not be considered as instances of adaptation to that method of dispersal.

The same statement applies generally to the chance deposition of the fruits or seeds of land-plants in the sea. They may be carried away to a great distance by ocean-currents, may float about for months, and finally be stranded on some remote coast. Experiments have frequently been made with a view to ascertain which fruits and seeds retain their power of germination notwithstanding prolonged immersion in salt water. As a result of these experiments it has been established that the seeds of *Asparagus officinalis*, *Hibiscus speciosus*, and several other plants do not lose their capacity for germination after immersion in sea-water for a period exceeding a year in duration, a fact which is in itself of great interest. But such results are without significance in relation to the dispersion of fruits and seeds, unless it be also ascertained that the fruits and seeds in question keep afloat upon the surface of the water. For most fruits and seeds sink at once, and sooner or later undergo decomposition at the bottom of the sea. The number of fruits or seeds capable of keeping afloat on the surface for any length of time is extremely small. Of the fruits which are found floating on the sea we may mention first the hard-coated fruits of the group of Palms named *Lepidocarynæ*. They have a smooth, scaly, completely closed envelope which is impermeable to water, and looks very like a coat-of-mail, and, owing to the fact that this envelope is not in immediate contact with the fruit, but is separated from it by a layer of air, the fruits are able to float on the surface of the water. The large fruit of the Cocoa-nut Palm also is rendered buoyant by a substantial layer of fibres, which incloses a quantity of air, and is itself coated by a layer with fatty contents which prevents the infiltration of water. If fruits of this kind fall into the sea and are cast up by the waves, the seedlings inclosed in them may develop and become denizens of the shores to which they have drifted, provided the conditions, in respect of climate and soil, are such as to permit it. As a matter of fact, fruits cast up by the sea on to remote islands in the Tropics have been known to develop without any human interference.

The phenomena connected with the dispersion of fruits and seeds in still water are altogether peculiar. Currents arising from the slope of the ground do not occur in such water, whilst currents set in motion by the varying temperatures of different layers of water, for the most part, ascend and descend merely, and can occasion very little horizontal displacement of fruits and seeds. The wind is the only agency in

these circumstances that can supply the propelling force necessary to drive such fruits and seeds as can keep afloat from one shore to another. Special mention must be made of three groups of fruits and seeds belonging to this category. These are, firstly, dry fruits which are rendered buoyant by air-inclosing envelopes, as, for instance, in the case of the marsh-plants known as Sedges (*Carex ampullacea*, *C. vesicaria*, &c.), where the fruit is surrounded by an inflated utricle; secondly, the fruits of Water-Plantains, Flowering-rushes, &c. (*Alisma*, *Butomus*, *Sagittaria*, *Sparganium*, &c.), which are furnished with a thick air-filled cortical parenchyma; and, thirdly, the seeds of some Water-lilies. In the case of the white Water-lilies



464.—Dispersion of fruits and seeds by the wind.

¹ *Anthyllis Vulneraria*; two fruiting calyces are falling from the plant. ² Longitudinal section through a fruiting calyx belonging to the same plant; the pod is visible in the interior. ³ *Trifolium tomentosum*; one head of inflated fruiting calyx is detached, and another is still attached to the stalk. ⁴ Longitudinal section through a fruiting calyx belonging to the same. ⁵ *Medicago scutellata*. ⁶ *Ostrya carpinifolia*; branch with two fruit-spikes. ⁷ Longitudinal section through the saccate cupule which envelops the nut in this plant

(*Nymphaea*), each seed is enveloped in a coat (*arillus*), which loosely clothes the outer integument (*testa*) of the seed, so as to leave a layer of air between the two. In the species of the genus *Nuphar* there is no arillus, but the carpels separate when the fruit is ripe into two layers, of which the outer one is green and succulent, whilst the inner one is white and charged with air, and incloses a large number of seeds. In all these cases the seeds are enabled to float by their envelopes, and are driven along on the surface of the water by the wind.

In a similar manner the wind causes certain detached as well as aggregated fruits to roll along upon level ground. This phenomenon is observed particularly in regions where a long period of drought follows the short summer season of development; and accordingly the plants concerned are especially abundant in the vicinity of the Mediterranean Sea and in Steppe-lands. Several Umbellifers indigenous to the high

Steppes of the East produce smooth, ellipsoidal fruits about the size of a hazel-nut and so light that if one of them is laid on a person's open hand when his eyes are shut he does not perceive its presence. The extraordinarily small weight of these fruits is due to the fact that their structure includes a layer resembling the pith of the Elder. A fruit of *Cachrys alpina* measures 13 mm. in length and 10 mm. in thickness and weighs 0.07 gm.; another *Cachrys* fruit from Shiraz is 15 mm. long and 10 mm. thick and weighs only 0.06 gm. When fruits of this kind fall they are rolled along over the Steppe by the wind and only come to rest when they are caught in some crack in the parched clay soil or get lodged in a hole in a rock. A few Papilionaceæ also produce rolling fruits of the kind. One of the groups of species belonging to the Medick genus, of which *Medicago scutellata* (see fig. 464⁵) may be taken as a type, has pods which are spirally curled into round balls and which, when their seeds are ripe, detach themselves from their stalks and are rolled

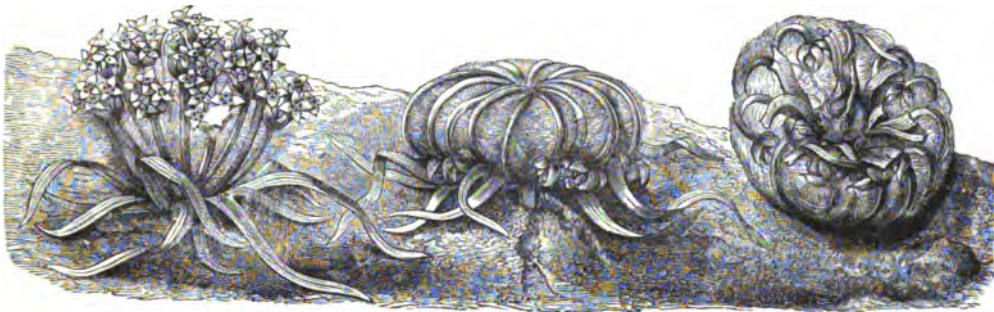


Fig. 465.—Dispersion of fruits and seeds by the wind. *Plantago Cretica*.

a little way along the ground every time there comes a gust of wind. The same thing happens in the case of *Blumenbachia Hieronymi*, a native of South America, belonging to the family Loasaceæ. Although the spherical fruit of this plant has a diameter of 2.5 cm. it only weighs 0.34 gm. when thoroughly dried. As soon as the seeds are ripe the fruit-stalk withers and the round fruits, which are then left lying loose upon the ground, are rolled away by the gentlest breeze. If their career is stopped anywhere, and they get wetted by rain, the openings which are already formed in them become enlarged and a quantity of wrinkled seeds fall out. *Paronychia Kapella* (see fig. 468⁶), a plant of wide distribution in the floral area of the Black Sea, where it grows on dry rocky soil, brings small fruits to maturity in the height of summer, each of which is surrounded by silvery white membranous bracts. When the season for the dispersion of these fruits arrives the entire tuft of fruits, which is in the form of a spherical glomerule, becomes detached from the branch on which it grows and lies lightly on the ground, where the least puff of wind imparts to it a swift rolling motion. Sometimes if the ground is uneven the rolling is converted into a hopping and springing motion, and occasionally such masses of fruit are raised by powerful gusts of wind and carried considerable distances through the air. In several species of Clover, such as *Trifolium globosum*, *T. subterraneum*, and *T. nidificum* (see fig. 468¹⁰) there are only a few perfectly

developed flowers in the cluster growing at the end of the flower-stalk, whilst a number of abortive flowers are crowded together in a tuft in the middle of the inflorescence. At the season when the legumes are formed from the fertile flowers the calyx-teeth of the abortive flowers increase in size and assume the shape of long hairy bristles, which bend over outwards and form a loose globular inclosure round the head of leguminous fruits. These balls afterwards become detached from the stalk and are rolled away by the wind.

Even entire plants are in some cases uprooted or have their stems severed from the roots at the base in the fruiting season, and are then rolled along like balls by the wind. The most remarkable instance is that of *Plantago Cretica*, which is shown in fig. 465. This is an annual plant possessing an abbreviated main axis from which springs a tuft of stiff, erect flowering stems. When the fruits begin to ripen the stems curve down in coils to the periphery of the plant, and by so doing give a strong pull to the abbreviated axis and to the simple tap-root, which is inserted in the earth in a vertical position. The soil on which *Plantago Cretica* grows being completely dried up in summer is full of cracks, and the pull imparted in the manner described is in consequence sufficient to uproot the plant. The plants now in the fruiting stage have the form of flattened balls and are very light, so that the entire structure is rolled along by gusts of wind. *Plantago Cretica* is also a type of the so-called "Steppe-witches" and "wind-witches", which are a source of so much wonder to travellers in the regions of Steppes. On the high table-land of Persia there is a plant named *Gundelia Tournefortii* which grows in loose, round, prickly sods, and has a tap-root deeply sunk in the earth. When the fruits are ripe the neck of the root rots away and the round sod then rests simply with its stiff lower branches in contact with the ground. Whenever the slightest wind begins to blow innumerable quantities of these sods are set in motion, and are thus dispersed over the plateau. The herbaceous plants of the Steppes of Southern Russia which exhibit the phenomenon of a decay of the bases of the stems in the fruiting season and a consequent liberation of the dry aerial portion of the plant belong to families of the most various kinds. The most common are *Alhagi camelorum*, *Centaurea diffusa*, *Phlomis herba-venti*, *Rapistrum perenne*, and *Salsola Kali*. It often happens that a number of these dry, branching herbs get hooked and entangled together as they roll along, until at length they form a ball as big as a cartload of hay. Such balls have also been seen lifted up by whirlwinds and driven bounding over the plain. It is not surprising that this marvellous phenomenon has appealed to the imagination of the inhabitants of the Steppes, and has even become a subject for witch-lore whence have arisen the names Wind-witch and Steppe-witch.

It only happens in a small proportion of these cases of rolling fruits, wind-witches, and the like, that the seeds are strewn out as they are bowled along; when this does occur it is usually occasioned by some unevenness in the ground which gives a sudden jog to the rolling body. In the majority of cases the seeds do not escape until the fruits are brought to rest by encountering some insurmountable obstacle, the reason being that the seed-vessels only open when they become wet.

This brings us back to the fruits of *Mesembryanthemum* and *Anastatica*, which were described on pp. 845, 846. Sometimes these also play the part of rolling fruits. The capsules of *Mesembrianthemum* detach themselves from their stalks, the plants of *Anastatica* become partially uprooted, and lie during the dry season of the year loose upon the earth. A puff of wind blows them into hollows in the ground or cracks in rocks, where they are held prisoners. The seed-cases, however, still remain closed. At last the winter rains set in, whereupon the capsules open, the seeds are washed out, and after a short time they germinate on the saturated ground, to which the rain has conveyed them.

Innumerable are the cases of wind-dispersed fruits and seeds which remain floating in the air for a period of more or less duration after severance from the mother-plant, and which have their fall retarded by special contrivances for the purpose. The conformation of fruits and seeds of this category must be such that the air offers great resistance to their fall, and it is important that they should possess as small a weight as possible in relation to their size. It is well known that the spores of Fungi often remain for a long time floating in the air as constituent particles of the dust. Some seeds, too, are so extraordinarily light that they also look simply like dust and are able to remain for a comparatively long period suspended in the air. Amongst such dust-like seeds those of Orchids must be mentioned first. A single seed of *Goodyera repens*, for instance, weighs only 0·000002 grm. Several other plants, particularly parasites and saprophytes which live in deep beds of humus, possess extremely light seeds, as is shown by the annexed table:—

Name of Plant.	Weight of Seed in grams.	Name of Plant.	Weight of Seed in grams.
<i>Stanhopea oculata</i>	0·000003	<i>Sempervivum acuminatum</i>	0·00002
<i>Monotropa glabra</i>	0·000003	<i>Parnassia palustris</i>	0·00003
<i>Pyrola uniflora</i>	0·000004	<i>Sedum maximum</i>	0·00004
<i>Umbilicus erectus</i>	0·000006	<i>Lepigonum marginatum</i>	0·00007
<i>Gymnadenia conopsea</i>	0·000008	<i>Spiræa Aruncus</i>	0·00008
<i>Orobanchë ionantha</i>	0·00001	<i>Veronica aphylla</i>	0·0001

To enable these seeds to float in the air for as long a time as possible they are more or less flattened, and their centre of gravity is so placed that they always present the broad side to the direction of descent. The same form of adaptation occurs in seeds which are shaped like leaflets, scales, or delicate discs. A compressed seed is usually surrounded by an attenuated margin, a membranous border, or a radiating fringe of extremely fine processes, as in *Funkia*, *Lilium*, *Tulipa*, *Fritillaria*, *Rhinanthus*, *Veronica*, *Lepigonum*, *Cinchona*, *Bignonia*, *Dioscorea*, and *Heliosperma* (see p. 423, figs. 318^{4, 5, 7}, and figs. 466^{2, 4, 5}). In some cases the entire pericarp is modified in this manner, as in *Hymenocarpus*, *Mattia*, *Peltaria*, *Ptelea*, and *Ulmus* (see fig. 467⁴, and p. 143, fig. 232²). Amongst Umbelliferae, Mimoseae, Papilionaceae, and Cruciferae cases also occur in which the mericarps, the segments of siliculas and lomenta, or the seed-studded valves of ordinary pods and siliques,

according to the particular plant considered, are in the form of scales and leaflets which become detached separately. Instances of this kind are afforded by *Artedia squamata*, *Megacarpæa laciniata*, *Mimosa hispida*, *Æschynomene glabrata*, and *Lunaria rediviva* (see figs. 467¹, 5, 11, and p. 445, fig. 339¹, and fig. 466¹).

With these forms may be classed also such fruits and seeds as are furnished with wing-shaped appendages. The wings are either produced from the seed-coat, as in Pines and Firs (see p. 441, fig. 335⁵), or else arise from the carpels. A single wing, which stands out to one side, is developed in the case of the pods of some tropical Leguminosæ (e.g. *Securida virgata* and *Centrolobium robustum*; see p. 445, fig. 339⁵), and in the separate parts of the double fruit of the Maple and of the

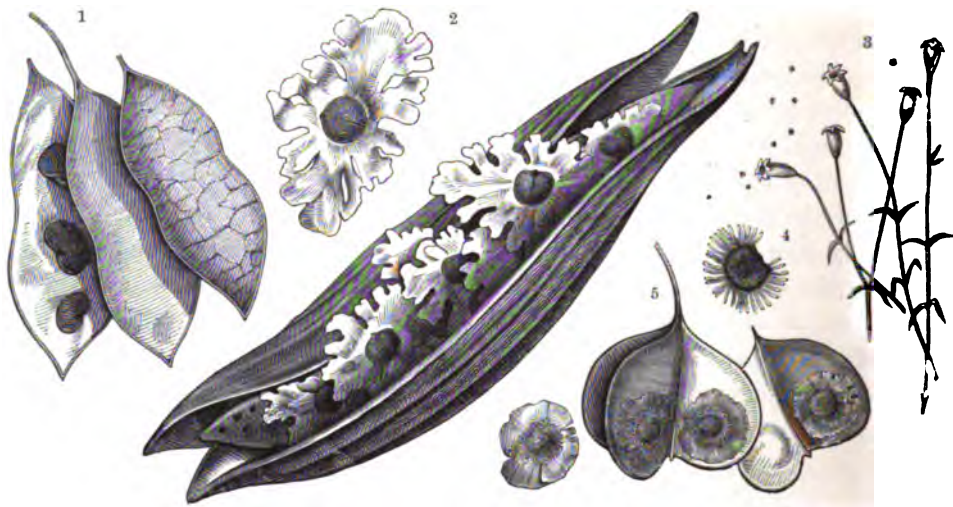


Fig. 466.—Dispersion of fruits and seeds by the wind.

¹ Silique fruit of *Lunaria rediviva*; the two valves of the fruit have become detached; seeds are fastened to the inside of each valve. ² Opened capsule of a *Bignonia* from which winged seeds are being carried off by the wind. ³ Capsule of *Heliosperma quadriidum* after dehiscence; the seeds are being shaken out by the wind. ⁴ A seed of *Heliosperma quadriidum* magnified. ⁵ Capsule of a *Dioscorea* after dehiscence, the winged seeds being blown away by the wind.

Banisterias, belonging to the Malpighiaceæ (e.g. *Acer Monspessulanum* and *Banisteria Sinemariensis*; see figs. 467⁷ and 467¹⁰). The achenes of Birches and of the Tree of Heaven (e.g. *Betula verrucosa* and *Ailanthus glandulosa*; see figs. 467² and 467¹²) bear two laterally placed wings in each case. The mericarps of many Umbelliferæ (e.g. *Opoponax Cretica* and *Laserpitium latifolium*; see figs. 467⁶ and 467¹³) have wings projecting from the back; the fruits of some Polygonums (e.g. *Polygonum dumetorum* and *P. Sieboldi*; see fig. 467³) are furnished with three wings, and those of *Triopteris bifurca*, one of the Malpighiaceæ, with four wings, of which two are large and two small (fig. 467⁹). In other cases some of the floral-leaves are transformed into wings for the fruit, as, for instance, in *Dryobalanops*, of the family Dipterocarpeæ, in which five sepals are in the form of long wings (see fig. 468⁵), and in *Gyrocarpus*, of the family Combretaceæ, in which two of the 4–7 unequal segments of the calyx are similarly adapted (see fig. 467⁸). It is of common occurrence for the fruits to become winged

in consequence of the continuous growth after the flower has faded and the ultimate desiccation of persistent bracts, as is seen in the Hop (*Humulus Lupulus*), the

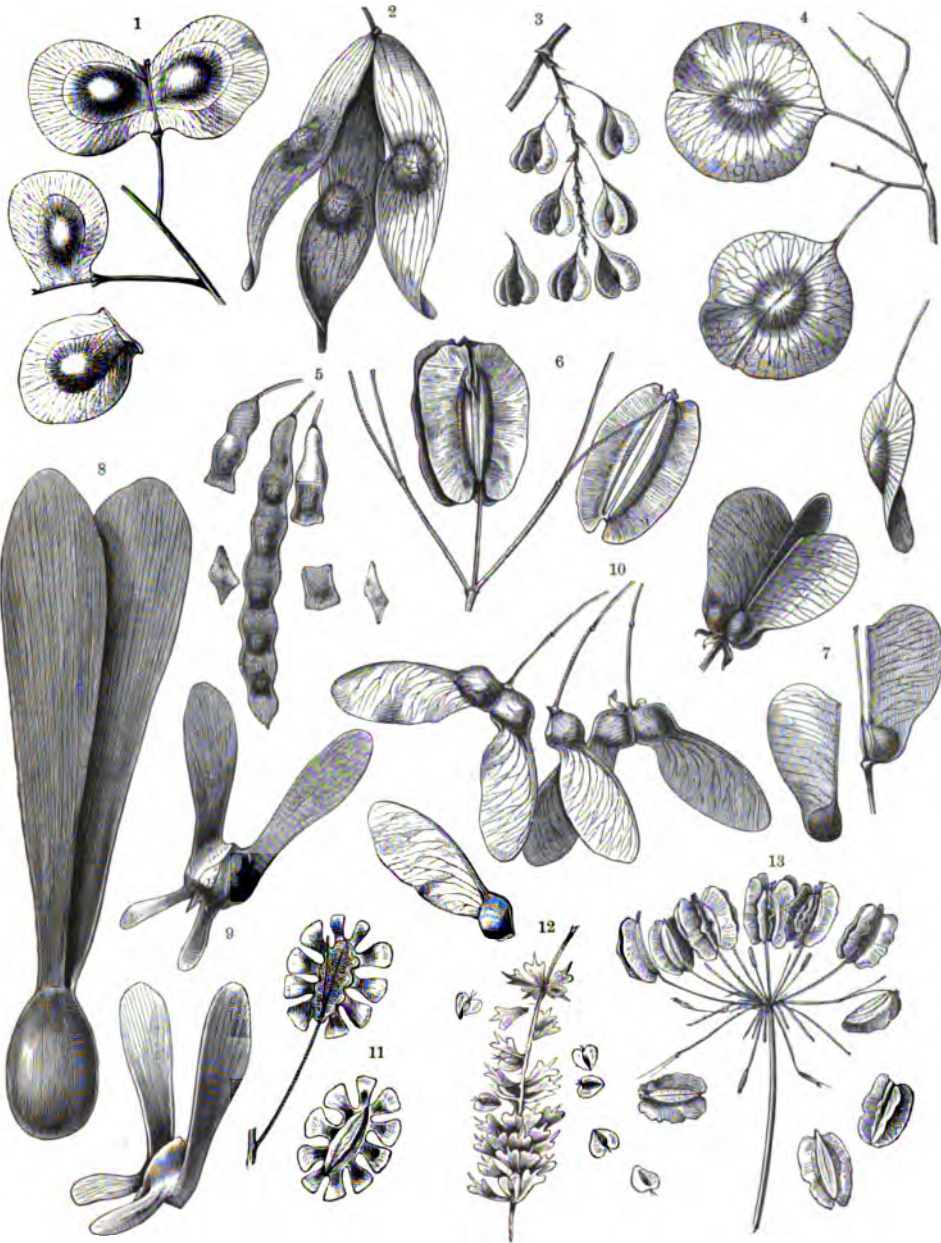


Fig. 467.—Dispersion of fruits and seeds by the wind.

- 1 *Megacarpus laciniata*. 2 *Ailanthus glandulosa*. 3 *Polygonum Sieboldi*. 4 *Ptelea trifoliata*. 5 *Eschynomene glabrata*.
6 *Opopanax Cretica*. 7 *Banisteria Sinemariensis*. 8 *Gyrocarpus Asiaticus*. 9 *Triopteris bifurca*. 10 *Acer Monspessulanum*.
11 *Artemisia squamata*. 12 *Betula verrucosa*. 13 *Laserpitium latifolium*.

Oriental Hornbeam (*Carpinus Orientalis*), and the Lime (*Tilia intermedia*) (see figs. 468¹ and 468²). In many cases, as, for instance, in the Tree of Heaven (*Ailan-*

thus), the two wings exhibit a slight spiral twist resembling a propeller; this occasions a peculiar gyratory motion of the fruit as it sails along in the air. Wherever there is only a single wing which projects from one side, the centre of gravity has an eccentric position, and the fruits and seeds of this class spin quickly



Fig. 468.—Dispersion of fruits and seeds by the wind.

¹ *Carpinus Orientalis*. ² *Tilia intermedia*. ³ *Armeria alpina*. ⁴ *Melica altissima*. ⁵ *Dryobalanops*. ⁶ *Paronychia Kapella*.
⁷ *Briza maxima*. ⁸ *Scabiosa graminifolia*. ⁹ *Humulus Lupulus*. ¹⁰ *Trifolium nidifolium*.

as they fall freely through the air. The motion in question is particularly well marked in the half-fruits of the Sycamore and the seeds of Pines.

The same object as is attained in the above cases by the development of alate processes is brought about in other plants by the transformation of dry bracts or floral-leaves into light, loose, saccate, or inflated envelopes round the fruits or seeds.

When quite dry, these envelopes are extremely thin and delicate, and sometimes their weight is still further reduced by a portion of the tissue being torn during desiccation, in which case the whole assumes a sieve-like or latticed appearance. The small fruit within the envelope defines the position of the centre of gravity, and consequently determines also the attitude of the structure as a whole that best adapts it to dispersion by the wind. In several Papilionaceæ, as in *Callipeltis cucullata* and the yellow-flowered species of Clover (e.g. *Trifolium agrarium* and *T. badium*; see figs. 469^{1, 2, 3, 4, 5}), the dried petals of the corolla are fashioned into an envelope which incloses the small 1-seeded legume, and in several species of Lady's Fingers (e.g. *Anthyllis tetraphylla* and *A. Vulneraria*; see figs. 464¹



Fig. 469.—Dispersion of fruits and seeds by the wind.

Trifolium badium. —¹ Inflorescence. ² Same with fruit ripened. ³ Flower. ⁴ Fruit enveloped in the dried petals. ⁵ Longitudinal section through the fruit in its envelope of petals.—*Verticordia oculata*. ⁶ Fruit. ⁷ Longitudinal section through the fruit. ⁸ Five "feathers" from the fruit. ^{3, 4, 5, and 8} magnified.

and 464²), and some species of Clover of the tribe *Vesicastrum* (e.g. *Trifolium fragiferum* and *T. tomentosum*; see figs. 464³ and 464⁴), the inflated calyx plays the same part. In many Labiates also (e.g. *Calaminta*, *Salvia*, *Thymus*), the calyx is converted into a dry, saccate envelope, which is severed from its stalk by any external stimulus, and then serves as a means of dispersing the ripe nutlets contained in it. In the Hop-hornbeam (*Ostrya*, see figs. 464⁶ and 464⁷), the small nut is enveloped in the sac-like bract; and in many Grasses, as, for instance, *Briza maxima* and *Melica altissima* (see figs. 468⁴ and 468⁷), the dry glumes constitute a covering to the small fruit which adapts it to dispersion by the wind.

One of the commonest devices for keeping fruits and seeds suspended in the air is of the nature of a parachute. This form of mechanism occurs in the shape either of tufts of hairs or of membranous borders. In Willow-herbs (*Epilobium*; see fig. 472⁶), Asclepiadaceæ (e.g. *Cynanchum*, see fig. 471⁶), and several Bromeliaceæ

(e.g. *Tillandsia*; see fig. 475²) only one pole of the seed is furnished with a tuft of hairs, whilst in *Adenium* (see fig. 471²), belonging to the family Apocynaceæ, both poles are so provided. In Valerianaceæ (e.g. *Valeriana*; see fig. 471³) and in Compositæ (e.g. *Senecio* and *Taraxacum*; see figs. 471^{1, 8, 9}) the tuft of hairs which acts as a parachute springs from the upper extremity of the achene. Sometimes the parachute and the body it keeps in suspension are connected by a slender stalk (e.g. in *Tillandsia* and *Taraxacum*); but usually the former is directly sessile on one extremity of the seed or indehiscent fruit as the case may be. In *Verticordia* (see figs. 469^{6, 7, 8}), of the family Myrtaceæ, a strange and beautiful parachute is formed by five petals which are in the form of little fans, each composed of ten



Fig. 470.—Dispersion of fruits and seeds by the wind.
Bombax. 2 *Anemone sylvestris*. 3 *Gossypium Barbadense*.

feather-like lobes, and in some Labiatæ, as, for instance, *Micromeria nervosa* (see fig. 471⁷), the radiating, hair-studded segments of the fruiting calyx constitute a similar apparatus. On the other hand, in several other Labiatæ (e.g. *Ballota acetabulosa*), in many Plumbaginaceæ (e.g. *Armeria*; see fig. 468³), and in several Dipsacæ (e.g. *Scabiosa*; see fig. 468⁸) the parachute is developed from the delicate, dry membranous calyx or from the epicalyx. Nor must reference to the Cape Silver Tree (*Leucadendron argenteum*, one of the Proteaceæ) be omitted. The fruits here are produced in large cones not unlike those of the Stone Pine (*Pinus Pinea*) in form and dimensions. Each bract of the ripe cone subtends a fruit consisting of a nut with persistent wiry style and stigma. The 4-lobed perianth also persists as a membranous parachute, its originally free apices having become connate above the nut and around the style. Ultimately the original attachment of the perianth below the ovary becomes dissolved, and as the nut falls out of the cone

the style (with nut suspended below) slides out of the hole, around which the perianth-lobes are connate, until its further progress is arrested by the button-like



Fig. 471.—Dispersion of fruits and seeds by the wind.

¹ *Senecio vulgaris*. ² *Adenium Hongkel*. ³ *Valeriana tripteris*. ⁴ *Typha Schuttelworthii*. ⁵ *Eriophorum angustifolium*.
⁶ *Cynanchum fuscum*. ⁷ *Micromeria nervosa*. ⁸ and ⁹ *Taraxacum officinale*. ¹⁰ *Salix Myrsinites*.

stigma. The perianth here forms a beautiful parachute, with the nut hanging freely below at the end of a string, like an enterprising balloon-gymnast.

From the fruits and seeds equipped with parachutes we pass to those which are embedded in masses of wool or in envelopes of silky hairs, and are thereby enabled

to remain poised in the air. The hairs arise either from the surface of the seed-coat (*testa*), as in the Cotton trees (*Bombax* and *Gossypium*; see figs. 470¹ and 470²), or else they spring from the base of the seed, as in Poplars and Willows (*Populus* and *Salix*; see p. 423, figs. 318³ and 318⁴; p. 424, fig. 319 and fig. 471¹⁰). In the Bulrush (*Typha*; see fig. 471⁴) they take their rise from the pedicels of the fruits, and in several Ranunculaceæ (e.g. *Anemone sylvestris*; see fig. 470²) from the achenes themselves. In other cases they arise from the floral-leaves, as, for instance, in the Cotton-grass (*Eriophorum*; see fig. 471⁵), where the structure which repre-

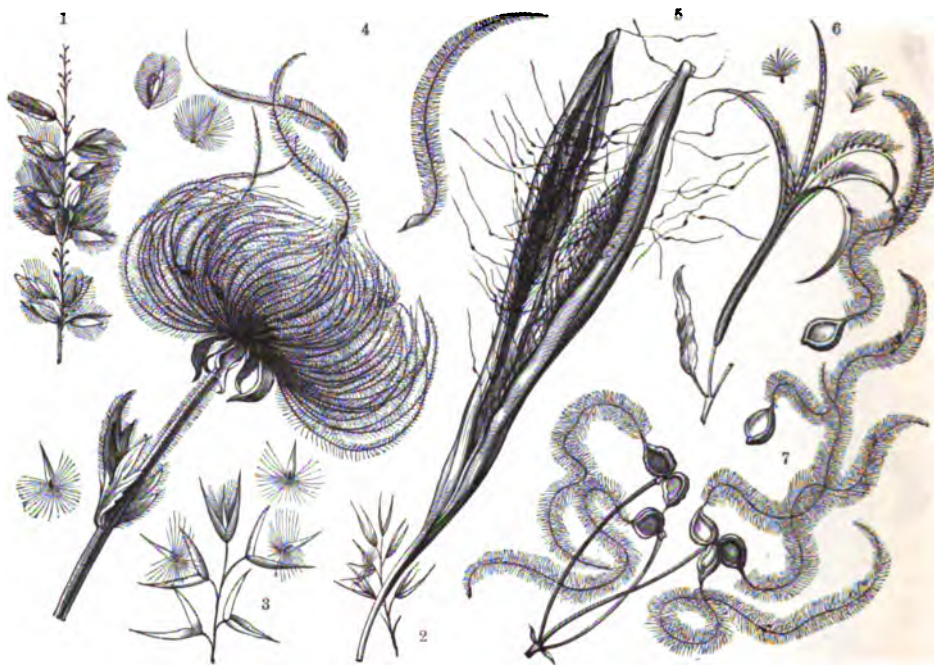


Fig. 472.—Dispersion of fruits and seeds by the wind.

¹ *Melica Balanexa*. ² *Calamagrostis Epigeios*; nat. size. ³ The same magnified. ⁴ *Geum montanum*. ⁵ *Eschynanthus speciosus*. ⁶ *Epilobium collinum*. ⁷ *Clematis Flammula*.

sents the perianth is transformed into delicate hairs, and in *Trifolium plumosum*, where the fruiting calyx is wrapped in wool. In many Grasses the glumes are beset with extremely fine hairs (e.g. *Melica* and *Calamagrostis*; see figs. 472^{1,2,3}), in *Micropus*, of the Compositæ, long hairs project from the scales of the involucre and envelop the entire capitulum in a flocculent mass, and in the Venetian Sumach or Wig-plant (*Rhus Cotinus*) the stalks of abortive flowers are covered with a woolly down, which serves for the dispersion of the fruits, whose stalks are usually free from wool. Lastly, we have the cases where the fruits or seeds are kept suspended in the air for a more or less prolonged period by means of special hairy tails. Either the seeds are tailed at both ends, as in *Eschynanthus* (see fig. 472⁵), one of the Gesneraceæ, in which the tiny seeds are furnished with two long hairs, one at each end, or else the style lengthens after the flower has faded and becomes converted into a spirally-curved tail, which remains attached to one side of the

achene, and acts like a parachute, as may be seen in *Geum*, *Atragene*, *Pulsatilla*, and *Clematis* (see figs. 472⁴ and 472⁷). In some Grasses, such as *Stipa* (see vol. i. p. 619, fig. 147¹), an awn is developed in the form of a long feather, which soars above the tightly-closed glumes inclosing the fruit.

Several of the fruits and seeds above described are directly exposed to the wind. Owing to the fact that the desiccation of the envelopes and stalks of the fruits at the time of ripening of the seeds renders certain layers of tissue brittle, a moderate wind is sufficient to cause the fall of such fruits, and the same gust that brings about their severance from the plant drives the fruit along in a horizontal direction. The fruit does not fall to the ground until the wind drops, or until its progress is arrested by some obstacle.

Many other fruits and seeds detach themselves spontaneously from the mother-plant when they are ripe, but are not directly exposed in consequence to the full shock of the wind. In these we find many contrivances for the purpose of ensuring that the parts to be dispersed shall be brought out from their shelter, and given over to the wind at the proper time. In some tropical Orchids which are epiphytic on the bark of old trees (viz. *Aerides*, *Angraecum*, *Sarcanthus*, *Saccolabium*, &c.), the capsular fruits contain, in addition to the small seeds, hair-like cells, with spirally-marked and obliquely-pitted walls (see fig. 473). *Vanda teres* (see fig. 475¹) may be taken as a type of this group. The hair-like cells in question are woven together into a sort of felt. They are extremely hygroscopic, and twist and turn about in a curious manner if the slightest change of condition in respect of moisture occurs.

When the valves of the capsules move apart under the influence of a dry wind, an active movement is simultaneously initiated in the matted hairs. The felt becomes to a certain extent puffed up, and consequently it squeezes out between the valves of the capsule, and drags the seeds, which are imbedded amongst the hairs, from the interior to the surface of the capsule, where they are liable to be blown away by the least breath of wind. This happens, as was said, when a dry wind is blowing. In wet weather the capsules close up, and conceal both hairs and seed once more in their interior. Similar phenomena may be observed in the fruit-capitula of some Composites whose fruits are spontaneously detached from the receptacle on ripening. In damp weather the loose achenes lie hidden in the involucrel cup, as though at the bottom of a basket, and the hairy pappuses appended to the achenes are clubbed together. When the atmosphere is dry, the involucre, which is composed of hygroscopic scales, opens, and the pappuses of the fruits within spring apart, and so act as



Fig. 473.—Seeds of the Orchid *Vanda teres*, which are moved from the interior to the surface of the capsule by hygroscopic hair-like cells, and are thus exposed to the wind; $\times 100$.

levers. The fruits are speedily raised by this means above the edge of the open involucre to a sufficient height to expose them to the wind. In some other Composites, such as the Dandelion (*Taraxacum*), the fruits do not detach themselves spontaneously from the floral receptacle when they are ripe. The segments of the involucre close together in wet weather, as do likewise the hairs or plumes of the pappus. In dry weather the involucre opens, whilst the feathers of the pappus diverge so as to assume the form of a parachute, and in that condition offer a comparatively large surface for the wind to act upon. A moderate gust of wind is now able to lift the fruits, with their expanded parachutes, off the receptacle and carry them away (see fig. 471^o). If no breath of wind stirs, they remain upon the receptacle; the damp atmosphere of evening causes both parachutes and involucre

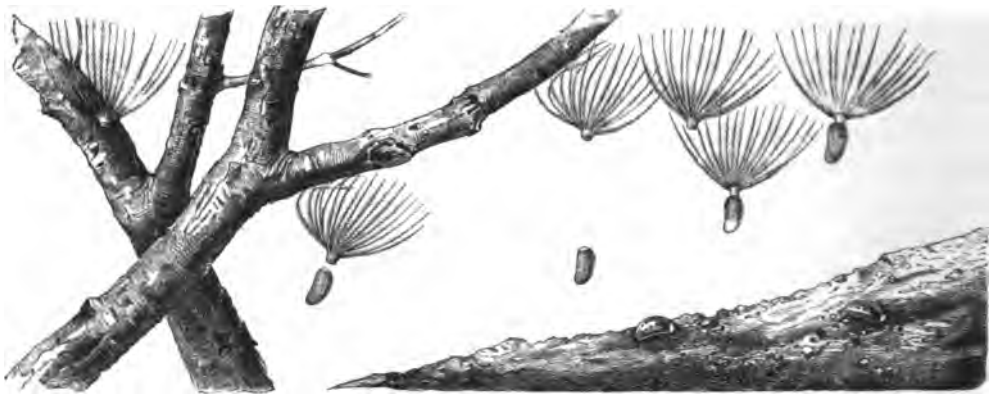


Fig. 474.—Dispersion of fruits and seeds by the wind. Fruits of a Thistle (*Cirsium nemorale*) floating in the air and becoming detached from their parachutes and dropping to the ground whenever they encounter an obstacle in the course of their flight.

to close up again, and the process of dispersion is suspended until next day, when the air is dry once more and the sun shining. In *Andropogon Ischaemum*, *Avena pratensis*, and many other Grasses, the flowering glume has an awn composed of spirally-marked and highly hygroscopic cells, and bent like an elbow, and this awn undergoes a marked spiral torsion, accompanied by a slight downward flexure whenever the air is dry. The distal arm of the awn is liable to get pressed against objects in the course of these movements, and it then acts as a lever in raising the fruits above the outer glumes. They are then easily blown away by a puff of dry wind. In several Scabiouises, also, the breaking up of the fruit-capitulum, and the raising of the fruits with a view to their dispersion by the wind, are occasioned by a bristling movement on the part of the hygroscopic setæ of the calyx. Each fruitlet in the Valerian is surmounted by a pappus of delicate feathery hairs. When the air is damp these feathers are folded together; when it is dry they become unfurled (see fig. 471³). In this condition of divergence, they present an ample surface to the wind, and the slightest gust detaches the fruits and blows them away. A similar phenomenon occurs in *Dryas*, and in some other plants; but we cannot now enter into the details of these cases.

In the case of Willow-herbs (*Epilobium*) and of some Pines (*Pinus nigricans*, *P. sylvestris*, &c.) the fruit-valves and fruit-scales which cover the seeds only open back under the influence of the sun's warmth, and when a dry wind is blowing, and the same wind which thus operates on the valves and scales also carries off the seeds the moment they are exposed, they being furnished with wings or tufts of hair with a view to aërial dispersion. The reader must be referred to p. 447 for a description of the manifold effects of a dry wind on the fruits and seeds in question. First, the dry capsules open; secondly, the seeds, hitherto lying in the interior of the fruits, where they are protected against moisture, are shaken out by the swaying to and fro of the elastic fruit-stalks; and thirdly, these seeds are caught up and scattered by the wind.

The distance to which fruits and seeds which are adapted to aërial transit by means of wings, hairy tails, parachutes, inflated envelopes or woolly coverings, as the case may be, are conveyed by the wind depends on the degree of perfection of their mechanism, on the condition of the air in respect of moisture, and on the strength of the current of air by which they are transported. When the weather is calm and sunny, innumerable of the lighter fruits and seeds are carried up to a great height by the ascending currents which are generated in the atmosphere; but they usually descend again after sunset at a little distance from the spot where they were taken up. Such excursions do not conduce so much to a dispersion of plants over large areas as to their deposition on shelves and in crevices of steep walls of rock, where seeds would not otherwise easily acquire a footing. Currents moving in a horizontal direction may, it is true, convey their freight of fruits and seeds over extensive tracts of country, but very exaggerated notions are usually entertained concerning the distances thus attained. Amongst the numerous species of fruits and seeds blown by storms of wind to the tops of the Alps and left upon the snowfields above the glaciers, not a single one derived from distant parts (*i.e.* from another district) has been found after careful examination of the deposited matter; and from this we may infer that, even on mountains, fruits and seeds are scarcely conveyed any further by a raging wind than when they are blown from one side of a valley to the other.

In many plants the wings or parachutes, as the case may be, only remain attached to the seeds or fruits for the period of their journey through the air. If the winged seed of a Pine gets stranded anywhere the membranous wing drops off, and the seed is then no longer capable of flight. This phenomenon is even more marked in the fruits of Thistles (e.g. *Carduus* and *Cirsium*; see fig. 474). The achenes, which are comparatively large, are supported by parachutes and float quietly in the air, but the moment one of them strikes against any obstacle the fruit severs itself from the parachute and falls to the ground. There can be little doubt that to this mode of dispersion must be attributed the common occurrence of Thistles at the foot of walls and in hedgerows, inasmuch as the floating fruits are carried against such structures with especial frequency. In other cases the fruit or seed maintains permanently a firm connection with the parachute, and the latter

serves to fasten it to some place where the conditions requisite for germination are present. For instance, when the seeds of *Tillandsia* (see 475²) come into contact with the boughs of old trees, as they are blown along in a horizontal direction, they fasten on to the bark where they are able to germinate immediately. Thus the pappus to which the seed owes its buoyancy serves subsequently to anchor it to a substratum favourable to its development.

The modes of dispersion of fruits and seeds through the agency of animals are



Fig. 475.—Dispersion of fruits and seeds by the wind.

¹ Capsule of *Vanda teres*, from which the seeds have been transferred to the air by means of hygroscopic hairs, and are being blown away. ² Open capsule of a *Tillandsia*; the seeds are being lifted out by the wind by means of their parachutes. If a seed is blown against the bark of a tree it is anchored there by the hairs of the parachute.

almost as varied as the different methods of dissemination by the wind. In many cases such dispersion is brought about by the animals using the fruits and seeds in question for food; the undigested parts are excreted, and any embryos which may have survived the passage through the alimentary canal subsequently germinate. As the fact of this mode of dispersion has been a matter of dispute amongst botanists, I determined to feed various animals with selected fruits and seeds, and to ascertain first of all whether the embryos preserve their vitality after passing through an animal's intestinal canal. Fruits and seeds belonging to 250 different species of plants were used for the purpose, and

the following birds were fed with them: blackbird, song-thrush, rock-thrush, robin, jackdaw, raven, nutcracker, siskin, goldfinch, serin-finch, titmouse, bullfinch, cross-bill, pigeon, fowl, turkey, and duck; and also the following mammals: marmot, horse, ox, and pig. After each meal the fæces were examined, to ascertain what seeds they contained, and were then laid on a separate bed of earth, and at the same time fruits and seeds of the same plants which had not been used for food were planted in an adjoining bed. It would be out of place to set forth here all the precautions which it was necessary to take in conducting these laborious researches, and I shall confine myself to a statement of the most important results obtained from 520 separate experiments.

As regards the mammals subjected to experiment very few words will suffice. Almost all the fruits and seeds administered to them, whether they took them voluntarily or unawares mixed with their ordinary food, were destroyed either at once or upon being chewed with the cud. It is true that a few millet-seeds germinated from the ox-dung, and must therefore have escaped being crushed during rumination, and that one or two solitary specimens of lentil-seeds and oat-fruits similarly passed uninjured through a horse, whilst *Cornus alba*, *Hippophae rhamnoides*, *Ligustrum vulgare*, *Malva crispa*, *Rhaphanus sativus*, and *Robinia Pseudacacia* all germinated after passing through a pig; but the number of the seedlings so obtained was scarcely appreciable as compared with the number of fertile seeds swallowed in the animals' food, and the fruits and seeds of about 60 other species of plants completely lost all power of germination during their passage through the intestines. The birds resolve themselves into three groups in relation to the matter in question. The first group includes those which grind up even the hardest fruits and seeds in their muscular and hard-coated "gastric mills" which are in addition usually filled with small stones and sand. Amongst these, some strip the fruits and seeds when they first lay hold of them, and thereby condemn them to destruction. To this group the following birds of those employed in the experiments belong, viz. the turkey, the hen, the pigeon, the cross-bill, the bullfinch, the goldfinch, the siskin, the serin-finch, the nutcracker, the titmouse, and the duck. No seed capable of germination was found under ordinary conditions in the excrements of these birds; only when on a few occasions food was forcibly administered to the hen and to ducks, so that their crops must have been overloaded, were a few seeds found to have escaped pulverization, and to still possess the power of development. The seeds in question belonged to *Arenaria serpyllifolia*, *Papaver Rhæas*, *Sisymbrium Sophia*, *Ribes rubrum*, *Ligustrum vulgare*, *Fragaria Indica*, and other species. Ravens and jackdaws form a second group, in that the stones of the drupes and hard-coated seeds of the berries which they ate passed uninjured through the intestine, whilst soft-coated seeds and fruits were all destroyed. It is worth mentioning in particular that after these birds had been fed with cherries their excrements contained cherry-stones 15 mm. in diameter, every one of which was able to germinate. Of the birds selected for experiment, the blackbird, the song-thrush, the rock-thrush, and the robin belonged to a third group. Of these the

blackbird was the least fastidious about its food. It even swallowed the fruits of the Yew without afterwards relieving its crop of the stony seeds, and it never rejected a single fruit that was mixed with its food. The song-thrush refused all dry fruits of 5 mm. diameter or more, even when they were mixed with the finely-chopped meat with which the bird was fed. They also avoided certain strong-smelling fruits, such as that of the Yarrow. On the other hand, the aromatic fruits of Umbelliferæ (e.g. *Bupleurum rotundifolium* and *Carum Carvi*) were eaten with great avidity. The seeds of the Tobacco-plant, Henbane, and Foxglove mixed with the food were not rejected and caused no ill effects, and no more did the berries of the Deadly Nightshade, which were devoured greedily. On the other hand, a song-thrush sickened after eating berries of *Phytolacca*. When fleshy fruits with seeds of diameter exceeding 5 mm., such as those of *Berberis*, *Ligustrum*, *Opuntia*, and *Viburnum* were introduced into the crop, the pulp passed thence into the gizzard, but all the seeds were thrown up. Many seeds, as, for example, those of *Lychnis flos-Jovis*, were carefully removed from the rest of the food with which they had been mixed. The seeds of fleshy fruits which were greedily devoured were thrown out of the crop if the stones which they inclosed measured as much as 3 mm. The interval of time between ingestion and evacuation was surprisingly short in the birds of the third group. A thrush fed with *Ribes petraeum* at 8 o'clock in the morning excreted numbers of the seeds after the lapse of three quarters of an hour, and seeds of *Sambucus nigra* were found to have passed through the alimentary canal in half an hour. The majority of seeds took from 1½ to 3 hours to perform the journey. Curiously enough, the small smooth fruits of *Myosotis sylvatica* and *Panicum diffusum* were retained for the longest period. Of the fruits and seeds which passed through the intestine of one or other of these birds, 75 per cent germinated in the case of the blackbird, 85 per cent in the case of the thrush, 88 per cent in the case of the rock-thrush, and 80 per cent in the case of the robin. The germination of fruits and seeds that had undergone ingestion and excretion was usually (i.e. in from 74 to 79 per cent of the cases) tardy as compared with that of similar fruits and seeds which had not been treated in this way but were only germinated for the purpose of comparison. Only in the case of a few berries (e.g. *Berberis*, *Ribes*, *Lonicera*) was the period of germination hastened. The seeds of such plants as grow on richly-manured soil (e.g. *Amaranthus*, *Polygonum*, *Urtica*) after passing uninjured through a bird's intestine produced stronger seedlings than did those which were cultivated without such preliminaries.

From these experiments it is evident that the dispersion of edible fruits through the agency of thrushes and blackbirds is not, as was formerly supposed, an exceptional phenomenon obtaining in the Mistletoe only, but one that may take place in the case of many other plants, and other observations prove that, as a matter of fact, it does take place. Plants possessing fleshy fruits are undoubtedly often disseminated in this manner. The occurrence of such plants as epiphytes upon trees, and also their unexpected appearance on the tops of high rocks and old walls thus receives a natural explanation.

The phenomenon in question also enables us to interpret the meaning of the changes undergone by fleshy fruits at the season when their dispersion becomes desirable, inasmuch as they serve the purpose of attracting animals, and the same consideration applies to the contrivances whereby animals are discouraged from taking the fruits before they are ripe. Mention has already been made of these latter contrivances on p. 444; and as regards the attraction of animals with a view to the dispersion of ripe fruits the following particulars are of especial interest: Fruits and seeds that are still unripe are hidden amongst the leaves of the mother-plant, have a green colour resembling that of the foliage, and are destitute of scent. On ripening the fruits are exposed, the coats of the fruits acquire a conspicuous coloration, and frequently emit a strong scent. In the cases where the seeds alone are dispersed and the pericarps are left behind, as, for instance, in *Pæonia Russi*, *Euonymus verrucosus* and *Magnolia grandiflora*, the capsules or follicles burst open, and the seeds are of a bright red or yellow colour, sometimes flecked with steel-blue and black, which renders them visible from afar. In the above-named species of *Euonymus* and *Magnolia* they emerge from the pericarps and hang at the ends of threads which renders them even more conspicuous. The particular colour assumed by fruits and seeds at the time of maturity varies according to that of the foliage by which they are surrounded. The different tones of red stand out best from a green environment; therefore, for plants with evergreen foliage (e.g. *Ardisia*, *Gaultheria*, *Ilex*, *Taxus*, *Arbutus Unedo*, *Arctostaphylos uva-ursi*, *Vaccinium Vitis-Idæa*) a red coloration is the most advantageous. Also in the case of plants with foliage which, although not evergreen, does not acquire an autumnal tint at the season when the fruits are ripe, e.g. the Strawberry, the Raspberry, the Currant, the Wild Cherry, and the Red-berried Elder (*Sambucus Ebulus*) the red hue of the fruits is of great value. On the other hand, red fruits would stand out but little against a background of foliage that had already donned the red or yellow tints of autumn by the time they ripened, and accordingly the fruits of *Ampelopsis hederacea*, *Cornus sanguinea*, *Prunus Padus*, *Arctostaphylos alpina*, *Vaccinium Myrtillus* and *V. uliginosum*, &c., are, as a fact, blue or black. Sometimes the fruits are black and the fruit-stalks red, as in *Sambucus nigra*, or the fruits are only coloured on the side exposed to view, as in the Apple and the Pear. The fruits of the Quince and the Pine-apple are set off by their yellow colour from the blue-green foliage. White berries, such as those of *Cornus alba* and *Symphoricarpus*, occur principally in plants which cast their leaves before the fruit is ripe. Standing out against the brown or gray background formed by the leafless branches and the fallen leaves of late autumn these white fruits are clearly visible. The extent to which fruits are advertised by their scents is a matter of common experience, and we need only refer for illustration to the Strawberry, the Raspberry, the Quince, and the Pine-apple.

Seeing that the seeds and stones containing seeds of the fleshy fruits eaten by thrushes and blackbirds only remain a short time in the crop and intestine of the bird, it is probable that the plants in question are disseminated by this agency to

the distance of a few leagues at most, in the course of a single year, and that it takes many years to distribute them, step by step, as it were, over large areas. We may reasonably suppose that distribution is effected principally in the direction of those parts of the world towards which thrushes and blackbirds are in the habit of journeying by short daily stages when autumn, the season of the maturity of most fleshy fruits, sets in.

It is well known that nutcrackers, jays, squirrels, and marmots, keep stores of food in larders, which they fit up in holes in rocks or in the earth or in some other secret hiding-place of the kind, and that such fruits and seeds as they conceal there are liable to be left permanently for one reason or another. The hiding-place may be forgotten, or, as is still more likely, the creature that occupied it may fall a victim to a bird of prey. The fruits and seeds may then germinate in the place of concealment, and, inasmuch as the latter is always more or less distant from the spot whence the fruits were taken, this must also be accounted one of the modes of dispersion of the plants in question. I have myself observed this curious phenomenon also in the case of the dissemination of the Arolla Pine (*Pinus Cembra*) by nutcrackers, of Beeches, Oaks, and Hazels by jays, and of Hazels by squirrels.

The subject of the dispersion of seeds by insects may be most conveniently dealt with in this connection. Otto Kuntze observed how ants fasten on to the pulp which surrounds the seeds of *Carica Papaya*, and push the seeds before them in companies of three, and Lundström narrates that the seeds of the Cow-wheat (*Melampyrum*), after they fall out, are carried off to ant-hills. These statements early directed my attention to the subject of the dispersion of seeds by ants, and I found that the phenomenon occurs on a very large scale. The ant *Tetramorium cæspitum*, in particular, is indefatigably engaged throughout the summer in dragging seeds to the ant-hill and storing them up there. Other species, which live in holes in the earth, hollow trees, and such places (*Lasius niger*, *Formica rufibarbis*, &c.), exhibit this form of activity, but they are much more fastidious than *Tetramorium*. Many kinds of seed, which are at once pounced upon by the last-named if they are scattered in the path of those insects, are left untouched by other species. So far as my observations go, it is the seeds with smooth external coats, but with large micropylar and hilar caruncles (see p. 425) which are conveyed to the holes, as, for instance, those of *Asarum Europæum* and *A. Canadense*, *Chelidonium majus*, *Cyclamen Europæum*, *Galanthus nivalis*, *Möhringia muscosa*, *Sanguinaria Canadensis*, *Viola Austriaca* and *V. odorata*, *Vinca herbacea* and *V. minor*, and various species of the genus *Euphorbia*. The *Tetramorium* showed a preference for the seeds of *Sanguinaria Canadensis*, which possess a very conspicuous hilar caruncle. These seeds being comparatively large and heavy, three or four small ants join forces when one is to be transferred to a hole. There can be no doubt that the caruncle, affording as it does an easily accessible supply of food, constitutes the source of attraction to the ants, and induces them to carry off those particular seeds. Neither the smooth coats of the seeds nor their contents are touched by the ants. Only thus can we interpret the fact that the seeds

dragged by ants under the ground, or into crevices in walls, germinate in those situations in the following year. It sometimes happens also that here and there a seed is left behind on the route of the ants, and in that case the caruncle is usually eaten off. Such abandoned seeds likewise germinate in the following year, and this explains the fact that the routes traversed by ants are regularly planted with certain species of plants. For example, in the Botanic Gardens at Vienna, the presence of *Chelidonium majus* is a constant feature of the ant-runs.

The transport of fruits and seeds to spots more or less remote from the localities where the mother-plants grow, by animals which have a definite purpose in view in so conveying them from one place to another, is on the whole a rare means of dissemination, and is confined to comparatively few species. But the unintentional dispersion of fruits and seeds by animals is of much more common occurrence. The objects thus dispersed get stuck or hooked, or otherwise fastened to the animals in the course of the latter's wanderings, and sooner or later are got rid of by them as being an unpleasant encumbrance. The places where such fruits and seeds are deposited are, however, always more or less distant from the spot where they ripened, and, as a general rule, they afford favourable conditions for germination.

The adhesion of fruits and seeds to the feathers of birds and to the skin or fur of other animals is due either to the agency of water, mud, and moist earth, or to that of special sticky substances secreted by the plants. In the case of many aquatic and marsh plants, such as the genera *Alisma*, *Butomus*, *Carex*, *Myriophyllum*, *Phellandrium*, *Polygonum*, *Potamogeton*, *Sagittaria*, and *Sparganium*, the fruits and seeds are unprovided either with special organs of attachment or with viscid secretions, but as was mentioned on p. 847 they have the power of keeping afloat on the surface of the water. If one dips one's hand into a pond covered with floating fruits of this kind, and draws it out again quickly, a number of the fruits always adhere to the skin by means of drops of water. The same thing happens when water-fowl rise from the water after swimming about for a time. The beak, legs, and feathers of a bird that has been shot not infrequently have the fruits in question clinging to them after the water has run off. If the bird had settled upon another pond the fruits would no doubt have been transferred to it. Adhesion through the intervention of water is assuredly by no means an insignificant factor in the dispersion of fruits to moderate distances.

The agency of mud and wet, boggy earth in affixing objects to animals is especially efficacious in the case of the numerous small fruits and seeds, which are by this means caused to adhere to birds when they come to the water's edge to drink. Jackdaws, herons, and snipe are not very particular about cleanliness, and they are invariably found to be smeared with mud. Swallows, particularly the rough-footed species, are very important members of this category, as during their sojourn on the banks of rivers and ponds they get bespattered with particles of mud. It is true that they try to cleanse themselves from all such foreign matter, but when the season for migration approaches they become restless and excited and forget the morning toilet which, until then, is performed with great care. In the same manner

water-fowl when they migrate neglect their usual habit of assiduously removing all traces of dirt, and we know from the investigations made by Darwin how great is the number of seeds imbedded in the mud. From 6½ ounces of mud 537 plants germinated. In my own case the examinations of the mud obtained from the beaks, feet, and feathers of swallows, snipe, wagtails, and jackdaws resulted in about half as productive a yield of fertile seeds; but that is a sufficiently striking result; and when it is remembered that pigeons and cranes traverse from 60 to 70 kilometres in an hour, whilst swallows and peregrine falcons cover as much as 180 kilometres, it is clear that fruits and seeds affixed to these birds may be carried in a very short time over several degrees of latitude. The number of species of plants which are dispersed in this manner is, it is true, but small. For the most part they are water-side and of these chiefly small annual species, as is evident from the following list of those whose fruits and seeds I found most frequently in the mud taken from birds:

<i>Centunculus minimus.</i>	<i>Heliocharis acicularis.</i>	<i>Lythrum Salicaria.</i>
<i>Cyperus flavescens.</i>	<i>Isolepis setacea.</i>	<i>Nasturtium amphibium.</i>
" <i>fuscus.</i>	<i>Juncus bufonius.</i>	" <i>palustre.</i>
<i>Elatine Hydropiper.</i>	" <i>compressus.</i>	" <i>sylvestre.</i>
<i>Erythraea pulchella.</i>	" <i>lamprocarpus.</i>	<i>Samolus Valerandi.</i>
<i>Glaux maritima.</i>	<i>Limosella aquatica.</i>	<i>Scirpus maritimus.</i>
<i>Glyceria fluitans.</i>	<i>Lindernia pyxidaria.</i>	<i>Veronica Anagallis.</i>

Most of these species are distributed over all parts of the world, but they seldom remain for a long time in any particular locality. They often start up quite unexpectedly at places where migrating birds have rested and gone to drink. The extraordinary occurrence on the edges of ponds in Southern Bohemia of the tiny *Coleanthus subtilis*, which is indigenous to India, and the sudden appearance of the same species of grass in the West of France about twenty years ago may be unhesitatingly attributed to the mode of dispersion in question, as may also the occurrence of the tropical *Scirpus atropurpureus* on the shores of the Lake of Geneva and that of the Southern native *Anagallis tenella* on the shores of the Schwarzzsee at Kitzbühel in North Tyrol.

The instrumentality of rain-soaked earth on steppes, on ploughed fields, and on roads in sticking numbers of fruits and seeds to animals' feet, whether the latter be in the form of hoofs, claws, or toes, or to their hair or feathers, as the case may be, has been the subject of repeated investigation. In the hardened earth taken from the feet of birds Darwin found a large number of seeds, of which many germinated. Many weeds which grow on fields and roadsides (*Prunella vulgaris*, *Malva rotundifolia*, *Potentilla anserina*, *P. reptans*, *P. supina*, *Ranunculus sardous*, &c.) depend mainly on this mode of dispersion. According to an informant, the suckers of the Gecko (a kind of lizard adapted to running about on smooth rocks and walls) are sometimes beset with fine seeds, and there can be no doubt that certain plants may be disseminated by such means over steep declivities of rock.

The excretion of sticky substances by fruits and seeds themselves must naturally

promote their becoming attached to animals. Although the adhesive materials mentioned in vol. i. on p. 615 as exuding from the fruits and seeds of various Composites, Crucifers, Labiates, and Polygonaceæ when they are wetted may be primarily devoted to fixing those structures to a substratum where they can germinate, they also frequently serve a second purpose in sticking them to passing animals. The best instance of this is afforded by the Meadow Saffron (*Colchicum*), whose seeds stick to the feet of cows, sheep, and horses by means of a comparatively large caruncle, which becomes viscid when it is wetted; in this manner the seeds are conveyed from one pasture to another. There is also an instance that has come under my own observation of a small owl (*Athene noctua*), which, in catching mice, brushed against Wormwood bushes (*Artemisia*), and when it flew away was all besmeared with the fruits, which had been rendered sticky by a previous shower of rain. The succulent berries of *Bryonia*, *Lycium*, *Solanum*, and various other Cucurbitaceæ and Solanaceæ burst on the slightest touch when they are over-ripe, and sometimes their seeds stick to the hairs and bristles of passing animals, and it seems not improbable, from the reports of travellers, that the fleshy *Rafflesias*, which are found principally on the routes frequented by large pachyderms, are disseminated in the same manner. The mode of dispersion of the seeds of *Nuphar* and *Nymphaea* is also very curious. Their dissemination by aqueous currents has been already dealt with on p. 848, but they are besides conveyed from pond to pond by water-fowl. In order to obtain the nutritious seeds these birds break open the fruits of Water-lilies with their bills, and in so doing are almost sure to leave some of the seeds, which are imbedded in a slimy mass, sticking to the feathers surrounding their bills. If they are suddenly disturbed at their meal they have not time to clean their bills before flying away, and so they carry the seeds with them, and do not rub them off till they reach another pond.

The fruits and seeds of several plants attach themselves to any animals that happen to brush against them by means of special glandular hairs or stalked glands. These latter consist of round cells or groups of cells which are borne on stalk-like structures springing from the epidermis, and which produce on their surfaces viscid, slimy, and resinous substances (see figs. 476² and 476⁵). The most diverse parts may be clothed with stalked glands. In *Boerhavia*, *Adenocarpus*, and *Pisonia* (see fig. 476⁴), it is the pericarp; in *Salvia glutinosa* (fig. 476¹), and the various species of the genus *Plumbago*, such as *Plumbago Capensis* (fig. 476³), it is the calyx; and in *Linnaea borealis* (figs. 476⁶ and 476⁷) it is a pair of bracts closely adherent to the fruit that is beset with stalked glands. In all these plants an absciss-layer is formed in the tissue of the fruit-stalk, and as soon as adhesion takes place the fruit is severed from the plant at the region of this separating or absciss-layer. Many plants—as, for example, the annual *Cerastium glutinosum*—have glandular hairs all over them, and when the seeds are ripe and the plants partially withered and only loosely rooted in the ground, a touch is sufficient to cause leaves, stems, and fruits to stick to the hair or feathers of any animal that may happen to pass. We may add that, in the case of every plant above referred to for illustration, the

phenomenon in question is not merely a matter of conjecture, but has come actually under observation.

About 10 per cent of all Flowering Plants possess fruits or seeds which are dispersed by means of clawed or barbed processes. This mode of dissemination is very like that whereby sticky fruits attain the same object. The part of the plant which is provided with these structures hooks on to the hairs, bristles, or feathers of any bird or other animal that happens to come into contact with it. The consequence is that it is torn away and carried off by the animal. This act of depredation is of course not intentional on the part of the creature that performs it; on the contrary, such appendages are a source of discomfort, and are got rid of as soon as

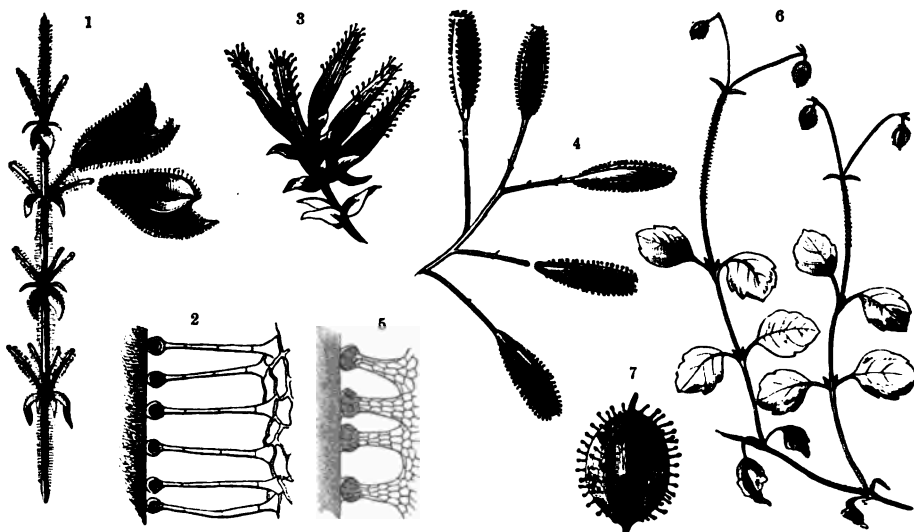


Fig. 476.—Sticky fruits.

¹ *Salvia glutinosa*. ² Stalked adhesive glands on the fruiting calyx of the same; $\times 60$. ³ *Plumbago Capensis*. ⁴ *Pisonia aculeata*. ⁵ Stalked adhesive glands on the fruit of the same; $\times 60$. ⁶ *Linnaea borealis*. ⁷ Fruit of the same; $\times 5$.

possible. But in many cases this is not accomplished until a considerable distance has been traversed, and sometimes the troublesome objects remain for weeks in the creature's coat or mane. The organs of attachment are either hooked at the tip or beset with barbs (see figs. 477² and 477¹⁸). In the latter case the barbs are borne on special rigid bristles or needles, and are either collected together at the top, as in a harpoon, or else are arranged in longitudinal rows as in a hackle for combing flax. Only in a few instances (e.g. in *Polygala glochidiata*, *Stellaria glochidiata*, and *Limnanthemum nymphæoides*) do these structures, which may be classed together as hooked bristles and hooked prickles, occur on the seeds themselves; usually they are appendages of the pericarp, and as such exhibit every degree of size possible, from the delicate, hooked bristles on the small nutlets of the Enchanter's Nightshade (*Circea*, see figs. 477⁸ and 477⁹) to the thick, firm claws on the fruits of the African Harpoon Fruit (*Harpagophytum procumbens*). The hooked spines of the latter fruits attain to the size of crows' feet, and are a notorious source of vexation to

ruminant animals, both wild and tame. In the Transvaal and on the Orange River the spring-boks sometimes tread upon them unawares, and when that happens the sharp claws grasp the hoof and the animal is driven to frenzy by the pain and gallops madly away, but is unable to set itself free from the instrument of torture. It is often several days before the capsule breaks up and falls off. The fruits, which

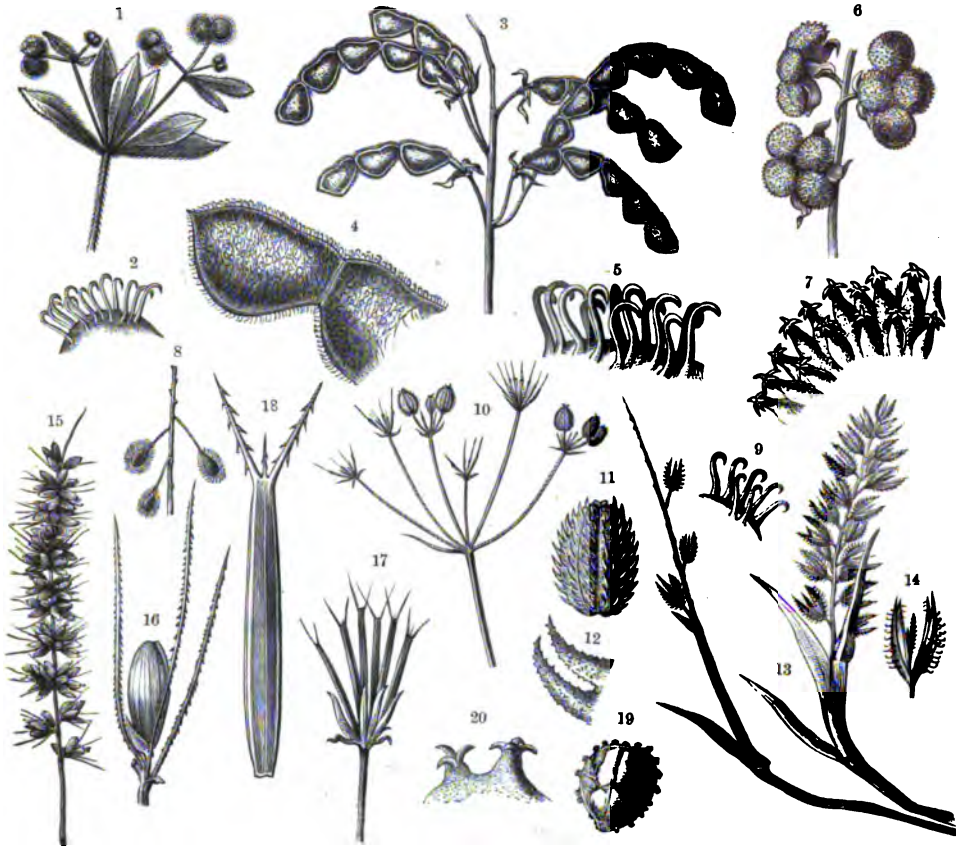


Fig. 477.—Fruits furnished with hooks.

¹ *Galium Aparina*. ² Hooked bristles of the fruit of the same. ³ *Hedysarum Canadense*. ⁴ A piece of the lomentum of the same. ⁵ Hooked bristles of *Hedysarum Canadense*. ⁶ *Cynoglossum pictum*. ⁷ Hooked prickles on the fruits of the same. ⁸ *Circea Lutetiana*. ⁹ Hooked bristles on the fruit of the same. ¹⁰ *Torilis Anthriscus*. ¹¹ Single fruit of *Torilis Anthriscus*. ¹² Curved prickles on this fruit. ¹³ *Lappago racemosa*. ¹⁴ Single fruiting spike of the same. ¹⁵ *Setaria verticillata*. ¹⁶ Fruit-bearing branchlet with involucre bristles from a spike of *Setaria verticillata*. ¹⁷ *Bidens bipinnata*. ¹⁸ Single fruit of the same. ¹⁹ Fruit of *Caccinia strigosa*. ²⁰ Hooked prickles on the fruit of *Caccinia strigosa*. ^{2, 4, 5, 7, 9, 11, 12, 14, 16, 18} and ²⁰ magnified.

are armed with hooked bristles or prickles, are so numerous that even a superficial account of them cannot be undertaken here, and we must content ourselves with mentioning a few of the most remarkable forms. Amongst these are the capsular fruits of *Krameria Ixina* and *Triumfetta Plumieri* (see figs. 478¹⁰ and 478¹¹), the sheathed achenes of several species of *Calligonum* and *Rumex*, e.g. *Rumex nepalensis* (fig. 478³), the pods of many Papilionaceæ (e.g. *Medicago agrestis* and *M. radiata*, *Onobrychis æquidentata* and *Hedysarum Canadense*; see figs. 478² and 478⁹, and

figs. 477^{3, 4, 5}), the nutlets of several Boraginaceæ (e.g. *Echinospermum*, *Cynoglossum*, and *Caccinia*; see figs. 477^{6, 7, 19, 20}), the several segments of the lomenta of *Æschynomene patula*, the jointed siliquas of *Tauscheria lasiocarpa*, the schizocarps of some species of the genera *Asperula* and *Galium* (e.g. *Galium Aparine*; see figs. 477¹ and 477²), and the mericarps of many Umbelliferæ (*Caucalis*, *Daucus*, *Orlaya*, *Sanicula*, *Torilis*; see figs. 477^{10, 11, 12}, and figs. 478⁶). Other contrivances exist, but are much rarer. Such are the bending of the sepals, when the fruit is ripe, so as to convert the calyx into a claw, as in the genus *Rochelia* (see fig. 478⁸), the assumption by the teeth of the fruiting calyx of the form of hooked prickles, as in *Valerianella echinata* and *V. hamata*, *Trifolium spumosum*, *Ballota rupestris*, and *Marrubium vulgare* (see fig. 478¹), the presence on the achenes of Composites of 1, 2, 3, or 4 hooked prickles in the place of a feathery pappus, as in *Bidens bipinnata* (see figs. 477¹⁷ and 477¹⁸), the barbed character of some perianth-bristles, as in *Scirpus lacustris*, and the crowning of the hypanthium (expanded receptacle) with hooked prickles, as in *Agrimonia* (see fig. 478⁵). As instances of the transformation of involucreal leaves into hooked bristles or prickles, we may mention *Xanthium* and *Lappa* (see figs. 478¹³ and 478¹⁷); whilst *Oryza clandestina*, *Paspalum tenue*, and *Lappago racemosa* (see figs. 477¹³ and 477¹⁴) may be taken as representatives of the Grasses whose glumes are furnished with similar appendages.

Sometimes the entire fruit has the appearance of a claw, or is armed with large barbs, by means of which it attaches itself to passing animals. This form of adaptation is especially striking in the pods of *Krameria triandra*, *Ornithopus*, *Biserrula*, *Coronilla scorpioides*, and *Scorpiurus sulcata* (see fig. 478⁴). The achenes of several Composites (e.g. *Rhagadiolus stellatus* and *Koelpinea linearis*) are claw-shaped, and *Koelpinea linearis* is provided in addition with a crown of sharp, curved barbs at the free extremity of each limb of the claw. In several species of the genus *Geum*, of which *Geum urbanum* will serve as an example (see figs. 478¹⁵ and 478¹⁶), the terminal portion of the segmented style breaks off when the fruit is ripe, and the remaining part becomes converted into a hooked spine which attaches itself to any object that happens to touch it. Similarly, hooked structures are developed from the styles of several Ranunculaceæ and Pedaliaceæ. Of the latter the most noteworthy are the fruits of *Martynias* (*Martynia lutea*, *M. proboscoidea*, &c.), which detach themselves from the herbaceous stem when the fruit is ripe—the stem being by that time in a decaying condition—and lie loose upon the ground. Two long curved clasps, with sharp hooked ends somewhat like the horns of a chamois in form, are developed from the styles, and by means of these the fruits cling to the feet of animals which tread on them. Indeed the whole family Pedaliaceæ is of interest on account of its multifariously hooked fruits. In addition to *Martynia* the already mentioned *Harpagophytum* belongs here, and several other genera, including a Chinese aquatic, *Trapella sinensis*. In this plant the fruit is provided with 3 long appendages wound up like watch-springs, which must readily hitch themselves on to the legs of aquatic birds—or possibly even to Fishes—and in addition 2 shorter, sharp, stiff spines, which no doubt preserve the fruits against

being eaten. *Rogeria* and *Pedaliium*, mentioned on p. 875, also belong to this family.

In other plants it is the fruit-stalk instead of the style which is transformed into a claw-like structure. In *Cyclamen Europæum*, for instance, the fruit-stalk undergoes spiral torsion and contraction. Formerly it was supposed that the object of this curious phenomenon was to draw the fruits into the earth, where the seeds would be favourably situated for germination. But this idea does not correspond to actual fact. The green capsules are drawn underground in the late autumn

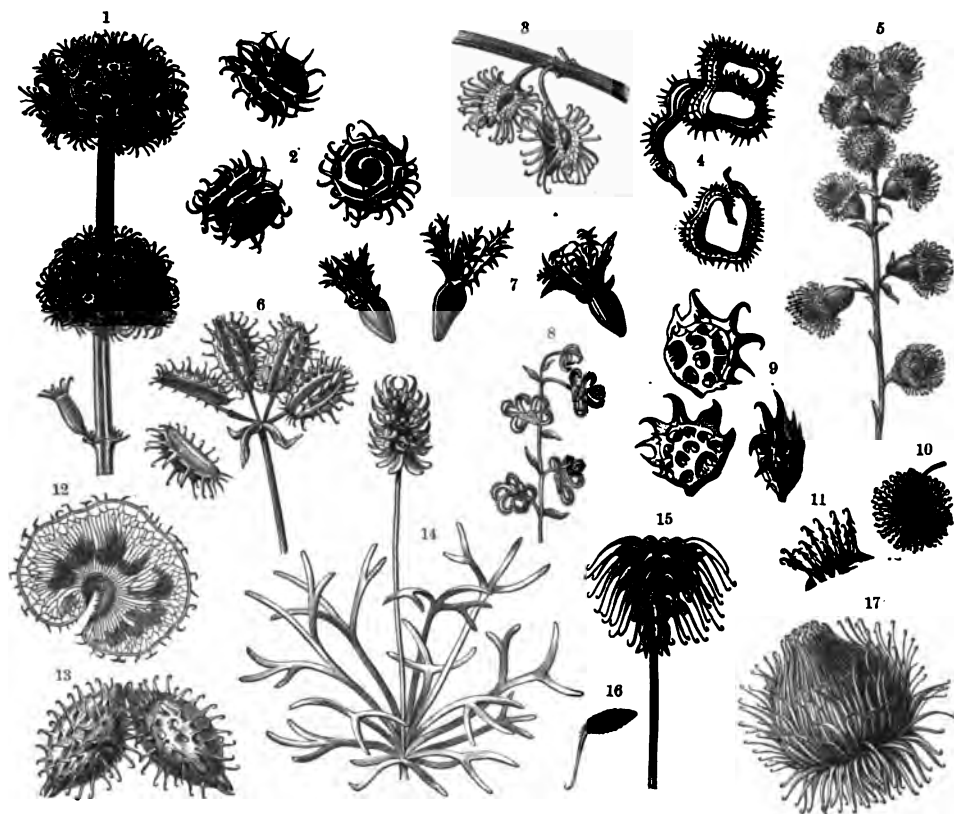


Fig. 478.—Fruits with hooks.

1 *Marrubium vulgare*. 2 *Medicago agrestis*. 3 *Rumex nepalensis*. 4 *Scorpiurus sulcata*. 5 *Agrimonia odorata*. 6 *Orlaya grandiflora*. 7 *Pteranthus echinatus*. 8 *Rochelia Persica*. 9 *Onobrychis æquidentata*. 10 *Triumfetta Plumieri*. 11 Hooked bristles on the fruit of *Triumfetta Plumieri* magnified. 12 *Medicago radiata*. 13 *Xanthium spinosum*. 14 *Ceratocephalus falcatus*. 15 *Geum urbanum*. 16 A single fallen fruit of *Geum urbanum*. 17 *Lappa major*.

when the seeds are still unripe. They pass the winter in the earth, and do not attain to complete maturity until the following summer. The desiccation and severance of the twisted fruit-stalk then has the effect of pulling the fruit out of the ground again, the lower portion of the stalk rots, and the part which is left forms a claw surmounting the capsule. The latter, which is still full of seeds, lies loose on the ground, and adheres to the foot of any animal that treads on it. The manner in which these seeds are besides dispersed by ants has already been referred to on p. 866.

With this curious form of fruit we may associate those in which the claws or hooked prickles are metamorphosed branches, or parts of abortive flowers situated on special ramifications. It will be sufficient to adduce two examples of this group, viz., *Pupalia atropurpurea*, of the family Amaranthaceæ, and *Pteranthus echinatus* (see fig. 478⁷) of the family Paronychiaceæ. In *Pupalia atropurpurea* short branchlets spring from the axils of the bracts; a few of them bear fruits, whilst the majority are modified into hooked prickles and form a tuft which easily fastens on to foreign bodies, and becomes detached from the main axis. *Pteranthus echinatus* has several short branchlets in each inflorescence situated close to the fruit, and bearing at their extremities abortive flowers with hooked sepals.

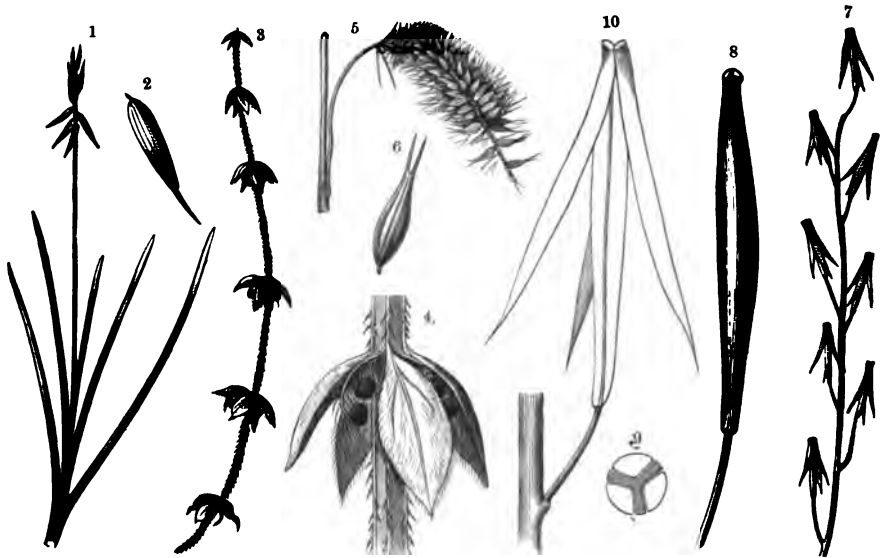


Fig. 479.—Fruits which hook on to or stick into passing objects.

¹ *Carex maritima*. ² Single fruit of the same. ³ *Galium retrorsum*. ⁴ A piece of the stem of the same. ⁵ *Carex pseudocyperus*. ⁶ Single fruit of the same. ⁷ *Triglochin palustre*. ⁸ Single unripe fruit of the same. ⁹ Transverse section through the same fruit. ¹⁰ Single ripe fruit with its component valves separated. ², ⁴, ⁶, ⁸, ⁹ and ¹⁰ magnified.

All the clawed or prickly fruits and clusters of fruit above enumerated easily come away from the mother-plant when pulled by the objects to which they have attached themselves. But there are other cases where the hooks and claws are firmly attached to the axis of the plant as a whole, so much so indeed that if the object to which they are fastened gives a pull a large piece of the stem is torn away, and sometimes even the entire plant is uprooted and carried bodily away. To this class belong the fruits of several Rubiaceæ, of which *Galium retrorsum* (see figs. 479³ and 479⁴) may be taken as a type. The fruit-bearing stem of this plant is at once broken off or uprooted when its barbed bristles catch in the coat of a passing animal. The species of the genus *Uncaria* also are examples of the kind. The long, creeping stems develop here and there clusters of fruit and at other spots abortive peduncles, which are metamorphosed into strong, sharp claws. When these claws get hooked to an animal's foot, a more or less large piece of the stem is torn away, and with it

the fruits developed upon it. Again, in *Specularia falcata*, *Valerianella echinata*, *Cornucopia cucullata*, and *Ceratocephalus falcatus* (see fig. 478¹⁴) the fruits do not sever themselves from the stems when their claws become attached to animals, but the entire plant is uprooted and carried away. A similar phenomenon is observed when a fruiting plant of *Setaria verticillata* is touched by one of the larger birds or some other animal. The fruits of this Grass are wrapped in awnless glumes and surrounded by involucrel bristles furnished with very sharp barbs (see figs. 477¹⁵ and 477¹⁶). When the bristles get fastened to an animal, not only the fruiting spike, but often a piece of the haulm as well, is dragged away, and sometimes the entire plant is uprooted and taken off. Such fortuitous appendages are very troublesome to the animal, and are got rid of as soon as possible. In many instances this is achieved without great difficulty by rubbing the coat against fixed objects, or by using the feet, snout, or beak, as the case may be, to disembarass the body. Sometimes, however, the sharp claws and barbs of the fruits are so firmly imbedded



Fig. 480. — Fruits with needle-like spines.

1 *Pedaliium Murex.*

2 *Tribulus orientalis.*

or entangled in the hair or feathers that their extrication is attended with much difficulty and suffering.

A mode of fruit-dispersion involving still greater pain to animals is that which is accomplished by means of straight, smooth prickles projecting from the fruit, and so situated as either to bore into the foot of any animal that treads upon it, or to stick into the coat of one that merely brushes by. Two groups of these fruits may be distinguished. The first group comprises those which lie loose upon the ground when they are ripe. To it belong *Acicarpus*, *Ceratocarpus*, *Salsola*, and *Spinacia*, in which the tips of the fruiting calyx harden and are transformed into spines standing straight up, and also *Rogeria*, *Pedaliium*, and *Tribulus* (see figs. 480¹ and 480²), in which the spines project from the fruit-walls. One of the species of the last-named genus, viz., *Tribulus orientalis*, is of common occurrence in the lowlands of Hungary, and is an object of dread to the shepherds of that region. The fallen segments into which the fruit resolves itself are armed with hard, sharp, comparatively long spines, and are often so covered with drifted sand that only the tips of the spines project above the surface (see fig. 480²). These prickles pierce deep into the hoofs and soles of animals that tread upon them, and are broken off the fruit by the efforts of the latter to rid themselves of the impediment. They are thus left sticking in the skin, and cause very painful, festering wounds. As examples of the second group of fruits furnished with sharp prickles as instruments of dissemination we

may take those of *Carex pauciflora* and *Triglochin palustre* (see figs. 479¹, 2, 7, 8, 9, 10). These fruits are borne on a stiff, erect axis, and when ripe are pointed obliquely downwards. They easily become detached from their stalks and are left sticking like needles in the skin or fur of animals that touch them.

Straight or slightly curved bristles and prickles may take part in another way in the dispersion of fruits. When they are set in rows like the teeth of a comb on the surface of a fruit or stand out in pairs from it, as, for instance, in *Carex Pseudocyperus* (see figs. 479⁵ and 479⁶), the woolly hairs and delicate feathers of some animals are liable to get entangled in them, and they are then dragged from their stalks. The same thing happens where the prickly processes projecting from the fruit cross one another, as in *Pterococcus*, *Sycios*, and many species of the Medick genus (e.g. *Medicago ciliaris*, *M. littoralis*, *M. sphaerocarpa*, *M. tentaculata*, and *M. tribuloides*), and where the surface of the fruit or of the fruiting calyx is covered with stiff bristles forming acute angles with it, as in *Asperugo*, *Myosotis*, *Parietaria*, *Physocaulis*, and *Torilis* (see figs. 477¹⁰, 11, 12). In many Grasses the awns which project from the backs of the glumes act as instruments for catching the hair of animals as they pass, and the latter is also liable to get caught between the nut and the hardened perianth-segments which surround it in several Chenopodiaceæ. It is not necessary for this that the bristles, prickles, or awns should be pointed, but it is advantageous for their surfaces to be rough or jagged, as in *Torilis* (see fig. 477¹²). We must not omit to mention also that the tufts of hair which clothe some fruits and seeds, and act as parachutes and wings, often get entangled in the hair or feathers of animals, and thus play an additional part in dissemination. The rough coats of sheep, goats, oxen, and horses are always found to have such hairy fruits and seeds affixed to them after they have passed over ground on which herbaceous Composites, shrubby Willows, &c., grow at the season when those plants are in fruit. I have myself removed from the coats of animals of the above-mentioned kinds fruits and seeds of *Anemone sylvestris* and of various species of the genera *Calamagrostis*, *Crepis*, *Cynanchum*, *Epilobium*, *Eriophorum*, *Lactuca*, *Lagœcia*, *Micropus*, *Populus*, *Salix*, *Senecio*, *Sonchus*, and *Typha*.

Anyone who has forced his way through a thicket of poplars and willows in early summer or through a clearing overgrown by *Calamagrostis*, *Epilobium*, and *Senecio* in late summer can bear witness to the manner in which fruits and seeds of the sort in question adhere to the clothes. Sticky and hooked fruits are also found upon one after such excursions, and it is perhaps not superfluous to remark that what has been said concerning the dispersion of seeds by animals must be taken to apply also to dissemination by men. Of course we are here referring to *unintentional* dissemination by human agency. We are here concerned with the cultivation of corn, vegetables, garden-flowers, edible fruits, forest-trees, &c.—i.e. with the purposeful dispersion of plants by men—in so far as many of the species in question establish themselves beyond the limits of the fields or gardens, where they have been sown or planted by man, through the operation of their natural means of dissemination and without human assistance, and further, inasmuch as weeds are often

introduced into the soil unawares with the seeds of other plants, and so grow in places where they would scarcely ever obtain a footing without the interference of mankind.

Looking back over this chapter we are struck by the following points:—In the first place, the commonest contrivances and adaptations are those which confer some other benefit in addition to that of dispersing fruits and seeds. The kind of structure most often encountered in this connection serves first as a means of protecting the flowers against unbidden guests of the animal kingdom and against injurious climatic conditions, subsequently as a means of scattering the fruits, and lastly, is instrumental in attaching them to a substratum and in promoting germination. Moreover, it appears from what has been said concerning pappuses and tufts of hair, that it is no rare thing for contrivances to be adapted equally well to the dispersion of fruits and seeds by the wind, by water, or by animals. It is also of great moment to observe that most, and perhaps all, Phanerograms exhibit two methods of disseminating their fruits and seeds, one of which is adapted to considerable distances, whilst the other is confined to the immediate vicinity of the mother-plant. The former may and does, as a fact, take place on a vast scale, but it depends upon the circumstances of the environment over which the plant itself has no control. It may, therefore, in some circumstances, be completely suppressed; in other words, dispersion to a great distance may take place but does not necessarily take place. Just as the best-made machine stands still unless its wheels are set in motion by an impulse from without, so the development of the most perfect flying apparatus is of no avail if there is an entire absence of wind at the time when the winged fruit is ripe; nor do the strongest hooks serve as means of dispersion if no animals come upon the scene. On the other hand, dissemination within short distances of the mother-plant always takes place if wider dispersion fails. Supposing the fruits of a Maple-tree, when ripe, are not blown far away by a strong gust of wind, they are ultimately detached spontaneously, and drop with a gyratory motion to the ground close by the tree which produced them. Again, in the case of the Squirting Cucumber, should the expulsion of the seeds from a fruit be caused by the touch of an animal, and the seeds stick to the latter's coat, they may be carried to a distance of many miles, but if no animal happens to pass the spot where the Cucumber is growing at the time when the seeds are ripe the latter are spontaneously ejected, and the dispersion so effected does not exceed a few paces in distance. In the event of the fruits of *Cyclamen* (see p. 873), which are borne on twisted claw-shaped stalks, not being carried away by animals, they remain lying on the ground in immediate proximity to the mother-plant and the seeds germinate in that situation.

These examples, to which might be added many others, show that the same law governs the contrivances adapted to the dispersion of fruits and seeds as was found to apply to the pollination of stigmas (see p. 390). Every species of plant exhibits some mechanism designed to bring about a cross with another species, or, at any rate, with another individual. If such mechanism is unsuccessful, other

contrivances are brought into play, the aim of which is to accomplish autogamy. The open flowers of *Viola sepincola* are adapted to cross-pollination through the agency of bees; should no cross take place, and no fruits be produced from the open flowers which bloom above the ground, cleistogamous flowers, hidden underground, develop and bring forth a number of fertile seeds as a result of the autogamy which inevitably takes place within their closed floral envelopes. *Viola sepincola* may also be taken as a type of those plants in which the fruits ripen underground and produce seeds which germinate at the spot where they were formed. Such plants have always been a source of wonder to botanists, and their number is not large. The best-known examples are *Arachis hypogæa*, *Cardamine chenopodiifolia*, *Linaria Cymbalaria*, *Phrynium micans*, *Trifolium subterraneum*, and *Vicia amphicarpa*. If these plants were only to bring fruits to maturity underground, or were to draw all their fruits below the ground as soon as the seeds were mature, in order that germination and the development of new plants might ensue at that spot, their behaviour would imply a renunciation of dispersion to any distance, and the phenomenon would be highly enigmatic. The puzzle is, however, satisfactorily solved when we take into account the fact that all these plants invariably have the chance of being dispersed to great distances either before the fruits become concealed in the earth, or by means of a second form of fruit which ripens above ground, and is evidently adapted to being scattered abroad through the agency of animals, or by means of aërial or aqueous currents.

LIMITS OF DISTRIBUTION.

The results of careful computations of the numbers of seeds produced yearly by a few selected plants show that on an average a plant of *Sisymbrium Sophia* yields 730,000, one of *Nicotiana Tabacum* 360,000, one of *Erigeron Canadense* 120,000, one of *Capsella Bursa-pastoris* 64,000, one of *Plantago major* 14,000, one of *Raphanus Raphanistrum* 12,000, and one of *Hyoscyamus niger* 10,000. Each of these seeds may give rise in the following year to a new plant, which, in its turn, may produce a corresponding number of seeds. Accordingly, if a Henbane-plant developed 10,000 seeds in one year, and 10,000 plants sprang from those seeds next year, and themselves produced 10,000 seeds each, by the end of five years ten thousand billions of Henbane-plants would have come into existence. Now, as the entire area of the dry land on the earth is approximately one hundred and thirty-six billion of square metres, and there is room for about 73 Henbane-plants on one square metre, if all the seeds referred to in our hypothesis ripened, the whole of the dry land would, at the end of five years, be covered with the plants in question. In the case of *Sisymbrium Sophia*, the normal multiplication, if unchecked, would, in the course of three years, cover an area 2000 times as great as the surface of the dry land with plants.

Any such exclusive occupation of the entire earth by one or a few species is prevented by a variety of causes. As regards land-plants, the sea, separating one

country from another, constitutes an important barrier to unrestricted distribution. Even narrow straits form an insuperable obstacle to any mode of dispersion which proceeds step by step, whilst broad seas also interfere with the dissemination *per saltum*, which is accomplished by roving animals and by currents of air and water. The number of species capable of being transported across the sea by birds is so small, that the dispersion of plants as a whole is not appreciably affected by this process. The same remark applies to dissemination by water. It is well known that fruits and seeds of American plants are occasionally conveyed to Europe by the Gulf Stream, and Linnæus tells us how the seeds of the West Indian Filbert (*Entada Gingolobium*) germinated after being stranded on the coast of Norway. There is no need to point out that tropical plants of the kind would not be able to establish themselves permanently in Western Europe were it only for the nature of the climate. But even amongst other American plants to which the climate would be no drawback, not a single species is known to have come to Europe by water without human intervention. Nor has any fruit or seed achieved the crossing of the ocean to Europe through the medium of the air. America possesses a large number of Willows, Composites, and Onagraceæ of her own, which have their fruits and seeds exquisitely adapted to aerial flight, and are themselves well fitted to thrive under the climatic conditions of Europe. Nevertheless not a single instance is recorded of such a plant migrating from America to Europe through the agency of the wind. The Compositæ and Onagraceæ, which have become naturalized in Europe since America was discovered (e.g. *Erigeron Canadense*, *Galinsoga parviflora*, *Solidago Canadensis*, *Stenactis bellidiflora*, *Oenothera biennis*, &c.), were introduced in other ways, and would neither have established themselves nor have been disseminated in Europe without human intervention.

The fact that a considerable number of American plants have found a home in Europe through the agency of man alone, and independently of the movements of birds or currents, is of great interest in connection with the present subject, inasmuch as it shows that the limits of distribution imposed by the sea are only temporary, that is to say, they are only maintained so long as the present distribution of land and water remains unaltered. If Europe and America were to become connected by a bridge of land, the possibility would arise of a gradual or sudden migration across the bridge, and such plants as have been conveyed from America to Europe by human agency would be able to immigrate without such assistance, and to disseminate themselves over Europe. The external conditions would offer no impediment to their naturalization in Central Europe any more than they now do to the installation of the same species when introduced by man. As the sea limits the distribution of land-plants, so the dry land restricts the dispersion of marine plants. The larger the expanse of land between two seas, the more difficult is it for the plants which inhabit them to exchange their homes. But here again the barrier is merely temporary; for were the land to sink in any part so as to become submerged, and the two seas thus become confluent, there would be nothing to prevent the plants living in them from passing from one to the other.

The nature of the soil may constitute an insuperable obstacle to a permanent occupation of a particular district by plants, and so act as a check to dispersion. Everywhere localities with sandy, loamy, or rocky subsoils alternate with loose, wet, and porous argillaceous earths. And yet how utterly different are the conditions under which plants growing on these two kinds of soil respectively must exist. Let us consider the case of a particular species, whose seeds are uniformly scattered over a district which includes areas with different kinds of soil. In the parts where the ground possesses the requisite properties for the maintenance of the species in question, the seedlings are able to establish a firm footing, whilst those seeds which fall on uncongenial soil perish. If millions of fertile seeds belonging to a marsh-denizen were scattered over a dry tract of land, not a trace of them would be found at the end of a twelvemonth. The extent to which the chemical in addition to the physical properties of the soil operate, in producing this result, and the part played by competition between different plants for possession of the ground, have been already dealt with (p. 495 *et seq.*). From these observations it is obvious also that the distribution of species, even within a district of restricted area, is materially influenced by the soil, and that the spots in such a district where a particular species thrives and multiplies are divided from one another by tracts where it does not exist. Those restricted sites in a locality, which offer favourable conditions to the progress of a particular species, and allow of its posterity maintaining possession of the soil, where, indeed, the species is permanently established are called the habitats of that species. The botanists of former times distinguished such habitats into a large number of different classes, from which we may select the following as the most important: fresh-water springs (*fontes*), salt springs (*salina*), brooks (*amnes*), torrents (*torrentes*), rivers (*fluvii*), pools (*stagna*), lakes (*lacus*), the sea (*mare*), shores of rivers and lakes (*ripæ*), sea-coasts (*littora*), marshes (*uliginosa*), swamps which dry up in the summer (*paludes*), peat-bogs (*turfosa*), places that are periodically flooded (*inundata*), pastures (*campi*), steppes (*pascua*), deserts (*deserta*), sunny hills (*colles*), stony places (*lapidosa*), rocky places (*rupestris*), sands (*arena*), argillaceous soil (*argilla*), loam (*lutum*), débris (*runderata*). Sufficient has been said to prove the fact that these habitats undergo various displacements, and are sometimes entirely lost, in consequence of changes effected in the soil in course of time through the action of running water and aerial denudation, or in consequence of the accumulation of humus.

The most potent influence affecting the dissemination and distribution of plants is that exercised by climate. The length of the days and corresponding duration of the sun's illumination, the temperature of air, ground, and water at the different seasons of the year, the condition of the atmosphere in respect of moisture, the quantity of water deposited by the atmosphere, and the times at which such deposition occurs in each year, the strength and direction of prevailing winds—not only are all these circumstances in general of the greatest moment to plant life, but each climatic factor stands in a definite relation to each species. If the fruits or brood-bodies of a plant are carried by any of the usual agencies of dispersion to a place

where the soil is favourable, but where the intensity of light, of warmth, or of moisture exceeds or falls short of the right measure for that particular species, the development of the species is arrested at the outset, and the plants die without leaving any offspring behind them. In this manner an absolute barrier is opposed by climatic conditions to the dispersion of each species. It must be added that the check may be given in one direction by one factor and in another direction by another climatic factor, and that not infrequently many conditions, collectively classed under the name of climate, exercise a simultaneous influence on the distribution of species.

The limits to the range of plants towards the Arctic and Antarctic regions and towards the summits of high mountains are imposed by the diminution of temperature and the increasing length of the winter, whilst the opposite boundary is encountered where the duration of daylight is still too short at the time of year when the temperature begins to be sufficient to cause the plants in question to sprout. The continental climate, which is distinguished by slight degrees of moisture, high summer temperatures, and low winter temperatures, checks those plants which suffer from dryness in summer or which cannot endure the cold of winter. On the other hand, in the case of species whose transpiration is unduly checked by a high degree of atmospheric moisture and which require an elevated temperature in summer in order to bring their seeds to maturity, bounds are set to dispersion by the climate of the sea-coast where comparatively slight variations of temperature occur during the year and where the summers are cool and the air damp. Meteorologists show us on special charts the distribution of the climatic factors by connecting all places having the same mean winter temperature, the same mean summer temperature, the same mean annual deposition of moisture from the atmosphere, and so forth, by lines which are termed isothermal, isohyetal, and lines of like mean annual rainfall respectively. The distribution of plants, in so far as it depends on climatic conditions, may be shown in the same manner by drawing lines connecting all the places at which any species is checked by climatic conditions. Such lines are called lines of vegetation, and when they run along the slopes of a mountain they coincide with the contour-lines. As each species of plant is checked in its progress towards the different quarters of the compass by different factors of climate, lines of vegetation may be drawn corresponding to the limits of range for each species to the north, north-east, east, south-east, south, &c. When all these vegetation-lines of a species are connected we obtain a curve which returns upon itself and is called a line of distribution. In most cases this line resembles an ellipse with the longer axis lying in the direction of the parallels of latitude. It is, however, not infrequently modified by influence of the nearest lines of sea-coast. The proximity of mountains also may cause variations which are principally of the nature of sinuses or bulgings.

The line of distribution incloses therefore the entire area of distribution in which the species in question finds suitable conditions and in which as a fact it grows and multiplies. Emphasis must be laid on the latter circumstance, because experience has shown that a plant-species does not necessarily grow in all the places where the conditions are favourable to its existence. Only the boundary-lines of the area of

distribution are dependent at the present day on climatic conditions; the manner in which the species has come to occupy that area has not been determined by the existing climate, but by geological processes which have always been the cause of the migrations of plants on a large scale. It also becomes a question in each individual case to what extent under past and present conditions the means of plant-dispersion would have free play.

The different areas of distribution vary greatly in size. Many species are only encountered on a single mountain, or in a particular valley, or on one island, as the case may be. These are called endemic species. As examples of such endemic species from the regions of Southern and Central Europe we may mention the following: *Iberis Gibraltarica* (Gibraltar), *Euzomodendron Burgæanum* (Central Spain), *Dioscorea Pyrenaica* (Central and Eastern Pyrenees), *Saxifraga florulenta* (Liguria and Piedmont), *Saponaria lutea* (South-western Alps), *Heracleum alpinum* (the Jura), *Hieracium Grisebachii* (the Oetzthal in the Central Alps of Tyrol), *Daphne petraea* (Val Vestino), *Rhizobotrya alpina* (Fassa and Belluno), *Gentiana Frölichii* (Carniola and Carinthia), *Wulfenia Carinthiaca* (Carinthia), *Sempervivum Pittonii* (Serpentine mountains in Upper Styria), *Schiverekia Podolica* (Podolia), *Viscaria nivalis* (Rodna Gebirge, in Northern Transylvania), *Pedicularis limnogenæ* (Bihar Mountains), *Hepatica Transsylvanica* (Southern Transylvania), *Haberlea Rhodopensis* (Rhodope Mountains in Roumelia), *Jankæa Heldreichii* (Thessalian Olympus), *Helichrysum virgineum* (Mount Athos), *Campanula Aizoon* (Mount Parnassus), *Hypericum fragile* (Eubœa), *Globularia stygia* (Mount Khelmos), *Genista Melia* (Melos), *Cephalanthera cucullata* (Crete), *Centaurea crassifolia* (Malta), *Petagnia saniculifolia* (Sicily), *Lereschia Thomasii* (Calabria), *Batatas sinuata* (Ischia), *Helichrysum frigidum* (Mountains of Corsica).

The species contrasting with the endemic as regards distribution, i.e. those whose range extends over almost the whole of the plant-inhabited earth, are called cosmopolitan. Their number is very small.

Only in the case of endemic species occupying an extremely restricted area do we sometimes find the plants evenly distributed over the whole area. They are more usually scattered unequally over the district in question. The spots where they grow in large numbers close together are separated by tracts where they do not grow at all, but where other species have taken possession of the soil, and the line of distribution then incloses separate habitats which are often at a considerable distance from each other. In such cases we speak of the area of distribution as sporadic. How far this depends on properties of the soil has been explained on pp. 495-500, and we need here only add that in mountainous or hilly countries the degree and direction of the inclination of the ground may have an important influence. Owing to the fact that a slope receives very different amounts of light and heat according as it faces north or south, different parts of a single mountain may exhibit diversities in respect of temperature and moisture as great as exist on flat ground between places separated by a degree of latitude. Also the differences in meteorological conditions between slopes facing east and west respectively, and

particularly those with south-east and south-west aspects, are much greater than is commonly supposed, and species are known, for example, which in a particular district invariably have their habitats on south-east slopes, whilst others occur only on slopes facing south-west.

It has been stated that the geological phenomena, and the changes of climate connected therewith, have at all epochs exercised an important influence on the migrations of plants, and have consequently had much to do with the displacements that have occurred in the lines of distribution. If a change occurs which results in the climatic conditions of 48° north latitude becoming such as previously prevailed at 46° north latitude, those species of plants whose range extended northwards as far as 46° proceed to take possession of suitable habitats beyond that limit and the northern line of vegetation of those particular species is sooner or later shifted northwards. On the other hand, the species which had up to that time enjoyed favourable conditions at 48° north latitude, but can no longer flourish under the new conditions, establish themselves on more suitable habitats lying further north, so that their southern line of vegetation undergoes displacement northwards. The eastern and western lines of vegetation may also be shifted in accordance with such alterations of climate as occur when an inland locality is converted into a maritime site or *vice versa*. These displacements may assume the aspect of a progression or of a retrogression, but in every instance the abandonment of the area of settlement will take the form of a migration of the plant-species concerned.

These migrations of plants which are accomplished independently of human influence take place as slowly or as quickly as the changes of climate to which they are due. In the case of species only capable of flourishing on particular habitats colonization must naturally proceed by leaps and bounds, whilst retrogression also cannot possibly take place uniformly.

The numerous habitats occupied by a species within the limits of its area of distribution are scarcely ever exactly alike in respect of the conditions which influence plant-life. Some habitats are pre-eminent on account of their advantageous position. The species in question develops most robustly, and multiplies most abundantly in that habitat. In the event, too, of a change of climate the species continues to live there longer than elsewhere, and may succeed in clinging to such isolated spots under fundamentally altered climatic conditions long after it has died out from hundreds of other habitats in the neighbourhood. If the species has meanwhile transplanted itself to adjoining territory and established there a fresh area of distribution, the spots where it has managed to survive in the old country appear like lost outposts wrested from the main area of distribution, or like islands lying off the shores of a continent. Such a state of things is by no means uncommon, and we are able to deduce therefrom facts not only concerning the former condition of the vegetable world, but also concerning the climatic conditions which used to prevail and as to the directions in which, in due course, plant-migrations have taken place. We shall have an opportunity to return to these interesting cases in the last chapter of this volume.

It is of great interest to note that the so-called "*petites espèces*" (see p. 581) of a particular genus often suppress and replace one another in adjacent regions and climatic zones. The first idea which suggests itself to one observing this phenomenon is that the differences of form exhibited by these races in neighbouring districts are the direct result of the diverse conditions of soil and climate under which they exist, and in former times this was the general opinion of botanists. Even at the present day many botanists hold the view that when a plant-species reaches a place where the climatic conditions differ from those of the home it has till then inhabited, it is able to adapt itself to the new environment, that such adaptation takes the form of an alteration of form, that the change is inherited by the plant's offspring, and that in this manner new species arise. But the results of experiments made on purpose to determine this matter do not justify any such opinion. No success has attended efforts to bring back various "*petites espèces*" to one and the same form by cultivation under precisely similar conditions, nor has any one of those species undergone the anticipated transformation on being transferred to the external environment which was looked upon as the cause of the variation in question. Either the species subjected to the new conditions succumbed thereto and perished without leaving any offspring, or else it underwent such alterations in form as are usually considered to be indicative of varieties merely (see pp. 508-514). These changes were not inherited by the offspring, and no "*petite espèce*" has ever arisen from a variation caused by properties of soil or climate. Such characteristics as are preserved by heredity, and constitute the essence of a species can therefore only have made their appearance, even in the case of "*petites espèces*", as a result of crossing. Whenever characteristics produced by a cross were in harmony with the climatic conditions of a district, the survival of the form which possessed those characteristics was assured. Such a form would be able to acquire through its offspring an area of distribution exactly co-extensive with the appropriate conditions of soil and climate. The two old species from which the new one sprang may both remain in the neighbourhood; it is, however, possible for one only of them to survive, and it is also conceivable that both should have died out. We must not forget in dealing with this question that the age of most species is much greater than was formerly considered possible, that in the case of the majority of species repeated displacements of the area of habitation have taken place since the species arose, that in the course of these displacements the species which belong to a single original stock, and are therefore allied in respect of the history of their evolution, have often been separated from one another, and that a proportion of them have perished and vanished altogether from the scene.

So long as two areas of plant-distribution, formed in adjacent zones or regions, do not touch anywhere, intercrossing between the denizens of those areas is very difficult, if not impossible, and even the "*petites espèces*" persist unchanged under such circumstances, and preserve their specific characteristics in their offspring. But even where the areas of distribution adjoin one another, and the distance between their native species constitutes no hindrance to cross-pollination, it is still possible

for two or more species to remain sharply marked off from one another owing to the fact of their flowering at different seasons. If the flowers of one species are already over when the other begins to bloom, no cross can take place between them under natural conditions. This obstacle to cross-pollination, which has been termed *asyngamy*, is the cause which enables very similar species sometimes to live close together without producing hybrids, and thus prevents the origin of new intermediate forms. For example, when *Aster Amellus* begins to bloom the flowers of the similar plant known as *Aster alpinus* are already over in the same locality, and again, at the season when *Solidago Virgaurea* unfolds its earliest blossoms, the flowers of the allied species *Solidago alpestris*, growing in the same neighbourhood, have already set their fruits. Such asyngamic species, of which mention has already been made on p. 510, are therefore found even in localities where their areas of distribution are contiguous, and even where those areas dovetail into one another, and where the various "petites espèces" grow together and transmit their specific characters unaltered to their descendants.

PLANT COMMUNITIES AND FLORAS.

Wherever the reign of nature is not disturbed by human interference the different plant-species join together in communities¹, each of which has a characteristic form, and constitutes a feature in the landscape of which it is a part. These communities are distributed and grouped together in a great variety of ways, and, like the lines on a man's face, they give a particular impress to the land where they grow. The species of which a community is composed may belong to the most widely different natural groups of plants. The reason for their living together does not lie in their being of common origin, but in the nature of the habitat. They are forced into companionship not by any affinity to one another but by the fact that their vital necessities are the same. It may perhaps be true that amongst the many thousands of plants inhabiting the earth no two are to be found which are completely alike in their requirements in respect of the intensity and duration of solar illumination, the concurrence of a particular duration of daylight with a certain amount of heat, the composition and quantity of the nutrient salts available at the places where the plants live, the amount of moisture in the air and in the ground, or, lastly, the character of the rainfall. This does not, however, exclude the possibility that in particular places similar demands may be met, and that different species with similar needs may flourish undisturbed side by side as men live together in one house or in one town, and, although their customs and their needs may not be exactly the same, yet form a society which is permanent and thrives, and wherein each member feels at home, because it rests upon common usages and is adapted to the local conditions. Nor is it impossible that each one may derive an advantage from the common life,

¹ Cf. A. Kerner von Marilaun "Oesterreich-Ungarns Pflanzenwelt", in *Die Oesterreichisch-Ungarische Monarchie in Wort und Bild*. Vol. i. p. 185 (1887).

that the associated individuals may support one another in the conduct of their lives, and that they may even be dependent upon one another.

A knowledge of the communities which exist within the realm of plants is of great importance in many ways. It throws a strong light, not only on the mutual relations of the different species which are associated by common or similar needs, but also on the connection of plant-life with local and climatic conditions and with the nature of the soil. It may fairly be said that in the various zones and regions of our earth no kind of phenomenon so thoroughly gives expression to the climate and the constitution of the soil as the presence of particular plant-communities which prevail, and, accordingly, the determination and description of such communities constitutes an important part of geography. Hitherto, it is true, only a few investigators have paid attention to this subject, and even they have given it but moderate study, the reason being probably that for the determination and description of plant-societies comprehensive data concerning all the species which flourish in the district under investigation are requisite, and the acquisition of such data has been greatly neglected of late years owing to the paramount attractions of other departments of Botany. The small progress of our knowledge in that direction is due also in part to the circumstance that a uniform method of investigating, describing, and classifying plant-communities has not up to the present time been successfully instituted.

The first thing that strikes anyone who takes up this subject is the fact that the different species of plants play very unequal parts in the formation of communities. Certain species predominate in respect of the number of their individuals. They determine the general character of the community, and form the groundwork of the vegetation as a whole, whilst the rest only make their appearance here and there, and look as though they were merely intercalated in the groundwork. It stands to reason that such dominant species, as they are called, belong chiefly to those which by nature grow together in numbers, and that those in particular are the most conspicuous which are aggregated together on a large scale.

Having regard to the dependence of plants upon soil and climate, the nature of which has been fully set forth in the first volume of this work, it might be expected that all plants living under identical conditions would have a common aspect or physiognomy. But this idea is only confirmed in the case of dominant species. The subordinate species may differ from the dominant ones, and also amongst themselves. One of the most usual causes of such differences of form is that the subordinate species of a community pass through the processes of budding, flowering, and fruiting at different seasons relatively, and that one species is adapted to the conditions which prevail in the spring, another to those of summer, and a third to those of autumn. It may also happen that certain reciprocal advantages accrue to neighbouring members of a community from the variety in the forms of their stems, foliage, and flowers. If one species affords at the right moment the shade required by another, or serves as a support for it to climb up, or protects it from high winds, such assistance not only does no harm to the community, but, on the contrary, con-

tributes materially to its preservation; and the same may be said of the cases where a contrast between the colours of the flowers of adjacent species promotes visits from insects, or where any other mutual help is afforded by plants growing side by side in a community. The general aspect of a community is scarcely influenced at all by diversities in the nature of the subordinate species, but depends solely on the dominant species which enter into its composition. These stamp their characteristic aspect upon the entire community, and determine the general impression conveyed to the observer.

This fact is of great moment when we come to the task of identifying, classifying, and naming the various communities formed by plants. Not only must the gregarious dominant species afford the basis of description in the case of each separate community, but their external appearance is the most important means of classifying in groups, according to similarity of aspect, the numerous communities which have been formed in the present period of the earth's history. Observations made under natural conditions, and extending over many years, have led to a division of plant-communities into the following nine groups:—

I. *Forests*.—The dominant species are plants with standard stems (see vol. i. p. 712). In accordance with the common notion of a forest, the stems which constitute its substructure are destitute of branches or leaves up to a certain height. Where this height is not much above that of a man, we speak of a copse; but if the standard stems remain branchless and leafless to a greater height, the assemblage of plants is called a forest proper. We might call these two kinds of forest (for the purposes of this chapter) high forest and low forest, though the terms are not in all ways free from objection; further, the circumstance that high forest has been low forest in the younger stages of its development is an additional reason against their adoption. If the trees of which a wood is composed are so close together that their top leaves and branches are in contact and form a sort of roof, the wood is said to be crowded or dense; whilst, if the trees are so formed and situated relatively to one another as to allow the rays of sunlight to penetrate between them and reach the ground, the wood is said to be thin.

II. *Scrub*.—The dominant species are shrubs, semi-shrubs, and cactiform plants growing in thickets, and never developing standard-stems, but branching from the very base, even when full-grown. The transition is quite gradual from erect scrub, reaching to a height of 2 or 3 metres, to those in which the stems lie upon the ground, and only lift their woody branches a few decimetres above it. It is the nature of shrubs and semi-shrubs to form thickets. Most of the bigger shrubs are impenetrable if not modified by human agency. In special situations, and under certain annually recurring conditions, woody plants of a kind, which usually develop into trees and exhibit standard-stems, may be dwarfed and assume the form of tall shrubs. For example, in the Alps, where trees growing near the boundary-line, beyond which their existence is impossible, are liable to be loaded with heavy masses of snow, and again, in the valleys annually exposed to avalanches, the Beech grows in regular thickets. They are, nevertheless, to be looked upon as forests which have

been dwarfed by peculiar circumstances to the level of low forest. If the congenial conditions referred to were to cease, a forest with standard-stems would grow up on the spot.

III. *Plains*.—The dominant plants are perennial and profusely-flowering herbs and undershrubs of gregarious growth. The form, direction of growth, and mode of ramification of the aërial herbaceous stems is always conspicuous, and may even be recognized when the foliage-leaves are of considerable size. Innumerable grades of this form of plant-community exist between Thistles and Umbellifers, reaching a height of 2 metres, which flourish on the Steppes, and the undershrubs scarcely 2 centimetres high, which grow on the débris-slopes in high mountain regions. No sharp line of demarcation can be drawn between them. Nor can any exact distinction be maintained between those Plains in which annuals and biennials and those in which perennial growths predominate. It is, however, possible within certain limits to distinguish between the different types of vegetation under this heading.

IV.—Another type, which may be termed the *frondose* type, has as its dominant plants such as have their stems either entirely subterranean, or else rising but slightly above the ground, whilst from their extremities are developed a crowd of fronds, branch-like leaves, or leaves with large laminæ. The stems are completely hidden by these leafy structures, so that their form and direction and the nature of their ramifications are never clearly visible. This type is conspicuously wanting in flowers. Where flowering-plants also form a constituent part, such plants either have precocious flowers, which have already passed into the fruiting stage by the time the mass of foliage has unfolded, and which subsequently disappear without leaving any trace (e.g. *Saxifraga peltata*, *Tussilago*, *Petasites*), or else their flowers are so lost amid the innumerable large foliage-leaves that they do not occasion any material alteration in the general aspect of the plant-community (e.g. *Funkia*, *Nelumbium*; see fig. 436, p. 775, and most Aroidæ). A special form of this type is exhibited on the surfaces of stagnant or gently flowing water, where discoid foliage-leaves rest upon the water and cover the surface completely. Of it there are several varieties depending on the dimensions of the constituent parts; *cf.*, for instance, Water Lilies and Duckweed.

V. *Ribbon-growths*.—The dominant plants are social hydrophytes with submerged stems and foliage-leaves, or with stem-like or foliaceous thalli. Sometimes forms possessing foliaceous thalli and long, flaccid, ribbon-shaped foliage-leaves predominate, sometimes forms which look like submerged leafy or leafless shrubs, but which differ from real shrubs in that they are herbaceous throughout. A gregarious growth of species with thalli or foliage-leaves which are split up into long narrow segments, or of species whose thalli exhibit a whorled system of ramification may also be present. Ribbon-growths may be separated into various subdivisions, according as one or other of these different sorts of plant predominates.

VI. *Reeds*.—The type is afforded by plants which grow in quantities together and have herbaceous stems of the kind called haulms and scapes. The stems are destitute of foliage-leaves (Horse-tails, Rushes, &c.), or else they bear long, narrow

leaves. Shoots bearing inconspicuous flowers spring up from the species which grow in tussocks, whilst the non-tussock-forming, but more continuously crowded types, develop haulms and scapes bearing an abundance of leaves. The tufted sedges afford an example of the former, and arundinaceous plants of the latter. A reed-like vegetation is developed both on marshy and on dry ground; instances of the latter occur in the Tropics and in Steppe-regions.

VII. *Carpet*.—The typical character is given by low, perennial plants, which form a close mat covering the ground. According as plants with narrow, stiff, grass-like leaves predominate, or such as form a soft, swelling carpet, two types may be distinguished; further, according to the nature of its most important constituents the community may be spoken of as a grass-carpet, herbaceous carpet, moss-carpet, &c. Carpets may grow either on dry or on marshy ground. Sometimes they are restricted to the immediate vicinity of springs or form merely a coating to slabs of rock, but they also spread over wide areas on mountain-slopes and basins. They belong especially to high mountains and to the Arctic regions.

VIII. *Incrustment*.—The dominant species are Thallophytes, which become rigid and brittle when dry or as a consequence of being incrustated with lime. The aggregations of these plants either form solid banks and reefs or else spread in the form of a loose covering over the earth, or they appear as incrustations on rock, earth, or sand. They develop both in the air and under water.

IX. *Felts*.—The dominant species are plants possessing thalli composed of delicate filaments which are more or less entangled together. They may grow in water either in a flocculent form or in coherent felted masses, and they also appear as a thin coating to stones or earth, in which form their characteristic colours render them visible from afar.

The names applied to the above nine classes or types of plant-communities are purposely devoid of reference to the particular alliances, families, or genera concerned in the formation of the communities, because the origin of the latter has nothing to do with the existence of any affinity amongst their constituent plants. Nor has it been possible to take into account the nature of the habitats or the situation of the zones and regions of the earth's surface where the communities grow. This is not the case, however, when we come to name the separate communities which belong to the above classes. For this purpose the use of a name which refers to the habitat, zone, or region where the particular community flourishes, or to the ruling species, genera, or families of which it is composed, is not only inevitable but actually desirable. The most convenient system of nomenclature to adopt here is that which has proved the best in all other descriptive sciences. In accordance therewith each plant-community is designated by two names, one denoting the class to which the community belongs and the other indicating its special characteristics.

In the present state of our knowledge it is impossible to name even approximately the plant-communities which are formed by the aggregation in various ways of some or other of the many thousands of species inhabiting the earth. I



Fig. 481.—Bamboo Forest in Ceylon (from nature by von Königsbrunn).

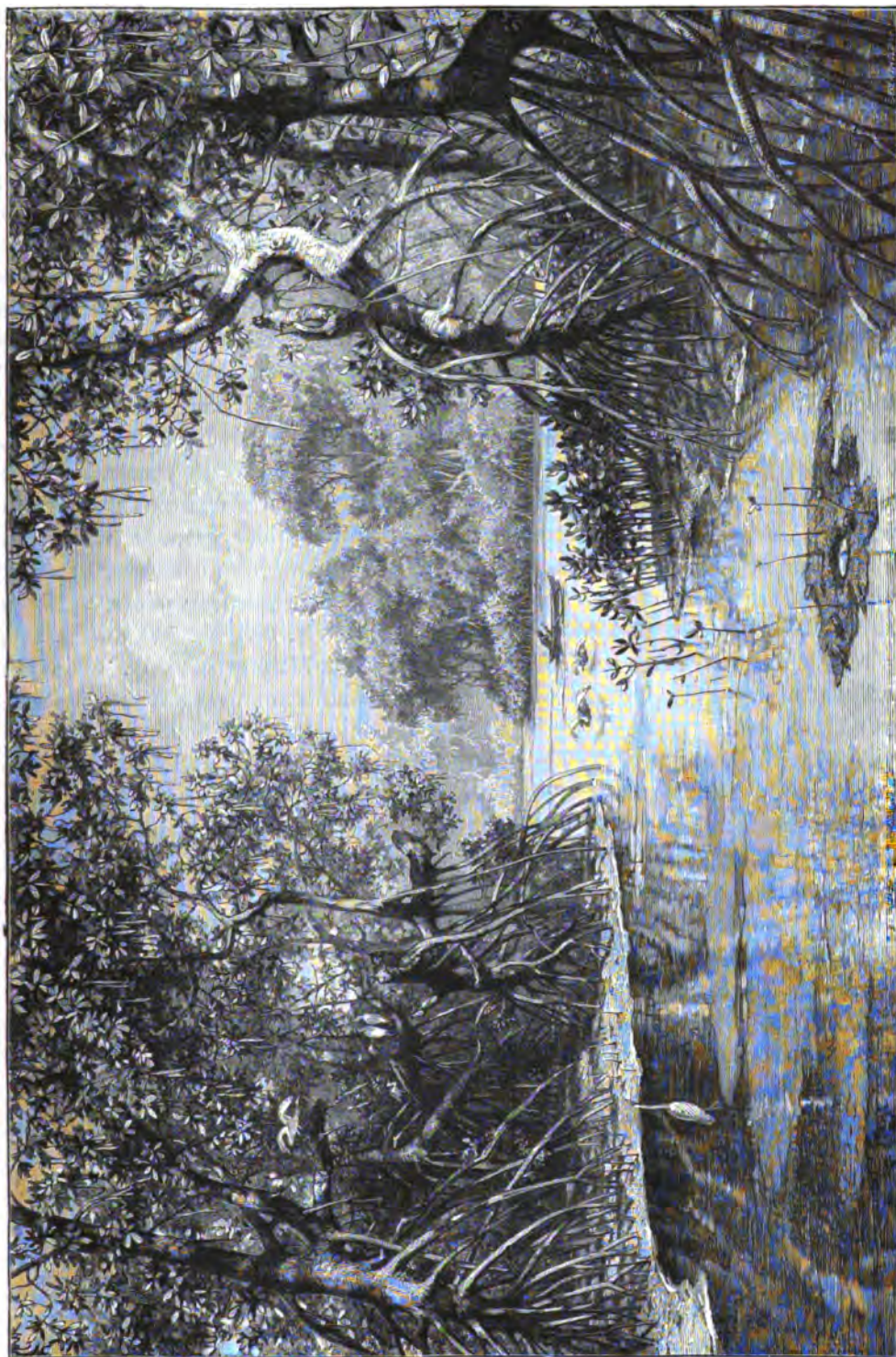


Fig. 482 — Mangrove Forest in India (from nature by von Ransonné)

will therefore only make a few observations on the subject, and draw attention to the most striking cases of plant-communities.

The greatest interest naturally attaches to forests which impress the observer by their size, and it is easy to understand why these have always been chosen for the most thorough investigation and description. As regards the species which are either the only constituents of the community, or at any rate its ruling members, we must first distinguish forests of deciduous Conifers and those of evergreen Conifers. A Larch forest (see fig. 354, p. 483) may be taken as an example of the former. Of the evergreen variety there is an extremely large number, owing to the fact that most true Conifers grow in dense forests. A forest of Spruce Firs is represented on p. 415, vol. i., a forest of Silver Firs on p. 717, vol. i., of Scotch Pines on p. 723, vol. ii., and of Arolla Pines on p. 724, vol. ii. Forests composed of Angiosperms are likewise differentiated into deciduous and evergreen. Amongst deciduous forests of this kind the Beech-woods (see p. 761), Birch-woods (see p. 721, vol. i.), and Oak forests (see vol. i. p. 716, fig. 173) of the North Temperate Zone are especially noticeable on account of the characteristic aspect exhibited in each case. Angiospermous evergreen forests manifest their greatest variety in tropical and sub-tropical regions. To the Tropics belong also a number of other special kinds of forest, such as those composed of Euphorbias, Casuarinas, Bamboos (see vol. i. p. 713, fig. 172), of Mangroves (see vol. i. p. 605, fig. 143, and p. 759, fig. 187), and of Palms (see vol. i. Plate VIII. opposite p. 712), respectively. Drawings from nature in the Tropics representing Bamboos and Mangroves are also given in figs. 481 and 482.

Scrubs, which are, so to speak, repetitions of woods or forests in little, may be similarly divided into groups. We distinguish between those in which the shrubs and semi-shrubs, which are predominant or in exclusive possession, are leafless and those where the shrubs are provided with foliage. Amongst the social plants of the first group switch-plants and certain cactiform plants play a prominent part (see vol. i. p. 331, fig. 80, and Plate IV. p. 446). The social plants of the second group are either evergreen or deciduous. The former are furnished with acicular or squami-form leaves which are appressed to the branches (shrubby Conifers and Heaths), or else are clothed with flat, expanded leaves. The case of Alpine Roses (see Plate X.) will serve as an example of the second variety. Amongst deciduous shrubs and semi-shrubs which grow sociably and form extensive scrubs we may mention Tamarisks, Spiræas, Roses, Dwarf-Almonds, Dwarf-Birches, Dwarf-Willows, Proteaceæ, Labiatae, Broom, and Mimosas.

As regards plains we must first distinguish those where the predominating perennial plants have no foliage-leaves, but are furnished instead with green, fusi-form shoots and branches of a foliaceous nature (e.g. *Salicornia*). Of leafy plants which occur as predominant members of plains we may mention Umbellifers, Thistles (see vol. i. p. 436, fig. 115), Agaves and Pine-apples (see vol. i. p. 657, fig. 153), and the Asphodel (see fig. 413, p. 729), as the most striking examples. The rest of the social suffrutices may be placed in three groups. The species

belonging to the first group, to which belong in particular many Composites, Caryophyllaceæ, Chenopodiaceæ, Papilionaceæ, and Cruciferae, are multifariously branched from the very base (e.g. *Artemisia*, *Gypsophila*, *Salsola*, *Melilotus*, *Crambe*); the species of the second group have upright stems which are unbranched up to the region of the flowers and bear entire leaves (e.g. many species of *Verbascum*, *Epilobium*, *Oenothera*, *Euphorbia*), and the species of the third group possess erect stems which have few branches, or none at all, but bear variously lobed and compound leaves (e.g. *Glycyrrhiza*, *Eupatorium*, *Tanacetum*, *Sambucus Ebulus*).

As regards the fourth or frondose type (cf. p. 888), we have already indicated certain varieties. In describing the different communities of this kind special emphasis must be laid also on the circumstance of the green laminæ being entire, as in *Petasites*, *Tussilago*, *Nelumbium*, *Asarum*, *Scolopendrium*, and *Saxifraga peltata*, or divided and incised, as in most Ferns, several Aroids, and a few Hellebores. We must also take into account whether the fronds or foliage-leaves are deciduous or evergreen, as in *Hedera* and *Helleborus niger*.

Ribbon-plants occur in great variety in both flowing and stagnant waters, be they fresh, brackish, or salt. The general aspect of any particular aggregate of these ribbon-like forms varies according to the area and shape of the foliage or thallus of the species concerned, and particularly according to whether the stems or the stem-like parts of the thallus are lax or packed close together so as to form a dense, pulpy matrix. The most conspicuous examples of social species are *Myriophyllum* with pectinate leaves, the Pond-weeds (*Potamogeton*) and Zannichellias with filiform leaves, the Pond-weeds with broad, translucent leaves (see vol. i. p. 551, fig. 136), the Grass-wracks (*Zostera*), *Vallisneria* (see vol. i. p. 667, fig. 155), and *Cymodocea*, also a few of the Mosses (e.g. *Fontinalis*), various species of *Fucus*, *Laminaria* (see vol. i. p. 588, fig. 139), *Sargassum*, *Macrocystis*, and *Cystosira* amongst Brown Seaweeds, species of the genera *Ceramium*, *Callithamnium*, *Polysiphonia*, and *Lemanea* amongst Floridæ, the species of *Bryopsis* and *Caulerpa* amongst the Siphonæ, and the several species of *Chara* and *Nitella* amongst Stoneworts.

The points whereon the classification of Reeds is based have been already indicated on p. 888. A number of distinct forms may be distinguished according as particular species of Horse-tail, Sedge, Rush, Restiaceæ, Scirpus, Calamagrostis, &c., prevail. The drawing of a Papyrus-swamp on p. 747 may be taken as typical of this class of vegetation. In the North Temperate Zone, of those which grow on dry ground the most prevalent species are those of the genus *Calamagrostis*. A great many Reeds occur in the Tropics and in the Steppe regions of both the Old and the New World, especially in the pampas, llanos, &c.

The plants which constitute the dominant members of carpet include both Phanerogams and Cryptogams. Of the former the most important are the interweaving and tussock-forming Grasses, Sedges, and Rushes, the interlacing, grass-leaved Caryophyllaceæ (e.g. *Alsine Rosani*, *Cherleria sedoides*, *Silene acaulis*), the species of Houseleek (*Sempervivum*) which form rosettes, the Saxifrages of the *Aizoon* group, the loosely-woven delicate Saxifrages which grow near springs, and

lastly, Montias. Of the Cryptogams almost all are Mosses, the chief species being the Sphagnums, Polytrichums, the species of *Dicranum* and *Gymnostomum* which grow in dense aggregates, and the Hypnums which cling together in loose mesh-work (e.g. *Hypnum Schreberi*, *Hylocomium splendens*, and *Hylocomium triquetrum*).

Only Lichens, Floridæ, and a few Stoneworts take part in the formation of incrustments. Extreme variety is exhibited by Lichens which combine to form crusts closely appressed to the substratum. The chief dominant plants are various species of *Acarospora*, *Amphiloma*, *Lecanora*, *Lecidella*, *Pertusaria*, and *Verrucaria*. The best-known and most widely-distributed incrustment is that which is formed by *Lecidea geographica* or *Rhizocarpon geographicum*, and imparts a characteristic colour to the blocks of stone on slaty mountains. A looser type of incrustment is composed of various fruticose Lichens, principally of *Cladonias* and *Cetrarias*, and are most striking in high mountains and in the Arctic tundra. A less important form is one composed of submerged Characæ and Floridæ incrusting with lime, e.g. by species of *Corallina*. The lime-incrusting species of *Lithothamnium* and *Lithophyllum* which combine to form solid bank-like incrustations known as nullipore-banks only occur in the sea.

Felts are formed by filamentous Algæ. The dominant plants are Scytonemacæ, Conjugatæ, Ulotrichacæ, Oedogoniacæ, Vaucheriaceæ, and a few others. The Conjugatæ, such as the various species of the genus *Spirogyra*, fill stagnant ponds with their green filaments; several of the Vaucheriaceæ grow in closely felted masses in water-courses or on damp earth, and several Scytonemacæ and Confervoidæ weave themselves into thin mantles over stones. Felts are but seldom of very conspicuous appearance. The best known is the thin felt formed by *Trentepohlia lolithus*, to which is due the red coloration of blocks of stone ("Violet-stone") seen in mountain regions.

It is only in rare cases that a plant-community is composed of a single species alone. For the most part two, three, or even more species of similar aspect are jointly predominant. At the same time it may happen that at one spot one species, at another spot another species is kept in check without any material alteration being thereby incurred in the general appearance of the particular community. Thus, for instance, the slopes of the schistose mountains of the Central Alps are clothed with carpets in which *Carex curvula*, *Juncus trifidus*, and *Oreochloa disticha* are dominant species. Here and there these three species share equally in the composition of the carpet, but in many places one is paramount, whilst the others sink into the background, so as to be scarcely noticeable at first sight. No further explanation is requisite to show that in such cases the community must not be named after one only of the dominant species.

As regards the subordinate species of a community it would be a great mistake to suppose that their occurrence is subject to no sort of rule. Though they seldom have any striking influence on the *tout ensemble* of the community their importance in it must not be under-estimated. Many of them are so constantly associated with

certain gregarious species that, where a plant of the one kind occurs, the presence of its companion species of the other kind may be inferred with certainty, and obviously due regard must be paid to such constant companions in any description of particular communities. A further circumstance which must not be overlooked is that up to a certain point the subordinate species may replace one another. Thus, for instance, that variety of carpet in which the Mat-grass (*Nardus stricta*) forms the dominant species, includes as subordinate species both in the Alps and the Carpathians *Homogyne alpina*, *Hieracium alpinum*, *Campanula Scheuchzeri*, &c. Certain other subordinate species, e.g. *Potentilla aurea*, *Hypochaeris Helvetica* and *Campanula barbata*, which are almost invariably present in the community in question when it grows in the Alps, are, however, replaced in the Eastern Carpathians by *Potentilla chrysocraspeda*, *Scorzonera rosea*, and *Campanula abietina*.

Special attention must be drawn to the fact that species which are gregarious in one plant-community occur as a mere sprinkling in another. When this observation is first made in Nature it is apt to lead one to suppose that it is a vain task to attempt to arrange the different communities in groups, and to define and describe each separate kind. But more careful study soon convinces one that the phenomenon in question, far from interfering with the scientific treatment of the subject, actually assists it, and that the history of plant-communities is elucidated thereby. It has been repeatedly remarked that mud newly deposited by water, exposed soil, and naked rock do not forthwith deck themselves in their permanent mantle of vegetation, but that first of all small Algæ, Lichens, Mosses, and various annual Phanerogams establish themselves and prepare the way in the course of time for other plants. This preparation, which was described in vol. i. pp. 257-268, consists not only in mechanical changes in the ground, but also in the admixture of humus derived from the parts of the first settlers which die off. The only species which take possession of ground so modified are such as differ entirely from the first colonists, and, curious to relate, the latter are gradually ousted by the new arrivals and driven from the field. But the second settlement has no permanence either. The quantity of humus arising from the death of plants increases from year to year, the soil becomes too rich for the plants in possession, and the process of eviction is now undergone by them at the hands of fresh species, which thrive on the rich soil, and gradually possess themselves of it. At least three successive series of settlers may thus be traced on every spot, and not infrequently the number is four or five. Now, if each of these groups corresponds to a particular community, which is as a matter of fact the case, the phenomenon described must produce the same impression as though the communities became transformed into one another in course of time. It is therefore necessary to recognize the existence of the incipient and decadent stages as well as that of predominance. In the incipient stage relics of the community which previously occupied the same spot are still to be found, and in the stage of decadence the first pioneers of the community that is to succeed make their appearance. When, for example, a carpet is invaded here and there by individual plants belonging to species indicative of communities which pertain to some other type,

such as scrub or plain, the occurrence does not in the least confuse the definition and description of the carpet. It only shows that for purposes of determination and description, whilst attending primarily to the stage of the community when development has reached its zenith, we must also take into account in each case the stages of incipience and decadence, and the relations to other communities.

Wherever the configuration and composition of the ground favour the formation of various kinds of habitat within narrow limits of space, there the particular plant-communities which correspond to those habitats develop in great variety close together. The boundary-lines of adjacent communities are disposed in a multitude of different ways in such cases. In lowlands where gentle hills alternate with shallow depressions, and where from sand one passes to clay, and thence, perhaps, to ground covered with saline efflorescence, the communities are not infrequently pieced together like the components of a mosaic. In other places those which cover a small area are interspersed like islands in the midst of the more extensive communities; and, again, in other cases the different areas are in the form of contiguous strips and zones. The last mode of distribution occurs chiefly along the margins of still or running water, and is explained by the uniform diminution of moisture in the ground as the distance from the water's edge increases, and in the case of still water also by the tendency of plants to advance from the margins towards the middle of the expanse of water where they grow, or, in other words, from the continuous transformation of the ribbon types which flourish in water into reeds, of reeds into plains, and of plains into carpets or into forests.

It very often happens that two or more plant-communities are intermingled, and that the whole exhibits a kind of stratification. A pine forest may exist by itself, that is to say, it may include nothing but dominant pines with, perhaps, a sprinkling of a few other kinds of tree, and the ground may be bare except for a bed of dry fallen needles. On the other hand, a carpet may have developed on the forest floor, whilst, in addition, a Bilberry scrub, a low scrub of *Calluna vulgaris* or *Erica carnea*, and a high scrub of Juniper may have obtained a footing, all of which communities are capable of existing independently without the shelter of the pines, and are often met with thus alone. But although the presence of the one community is not indispensable to the existence of the other, the fact of their occurring together shows that no injury is suffered on either side in consequence of the companionship, and it is much more likely that communities growing on the same ground are mutually helpful and protective. In many cases there is no doubt of this, as, for example, when a community of tall plants develops on soil previously prepared by a community of low plants without completely ousting them. We gather, then, that the conjunction of several communities is by no means fortuitous, that the association is always between certain particular communities, and that even here we find strict orderliness and subjection to definite laws.

Unions of communities formed in the manner above described have been termed *plant-formations*, probably from analogy with the combinations of strata of earth and stone which geologists call formations. The selection of this name is not quite

fortunate, but having been once introduced into the science, it must remain, and it is only necessary to point out that the communities united in a formation do not always exhibit any obvious stratification. Thus, for instance, in many tropical forests (see fig. 420, p. 741) communities are interpolated which belong to the most widely different types, and exhibit all possible grades in respect of the height to which their component plants grow. These communities occupy sometimes only a restricted area, sometimes a considerable expanse either down on the ground or midway between the ground and the tops of the trees; and, moreover, in all such formations there is always a sprinkling of climbing-plants and epiphytes, which make it quite impossible to discover distinct strata. In many other cases, it is true, the communities constituting a formation are in obvious strata. If we may compare the plant-formation to a building, the communities may be said to form the stories rising one above the other. Sometimes only two communities are superimposed on one another, sometimes it is possible to distinguish three or more strata or stories. There are formations in which each story belongs to a different class of community, but others exist also where two or three of the stories are of the same class, as, for instance, where several scrubs rise one above another, or where two forests are united, so that the crown of one species of tree forms an upper tier, and that of another species a lower tier.

The names of the different plant-formations should be chosen with regard to the community which forms the roof of the entire edifice of plants in each case, and which, therefore, projects above, and, in a sense, prevails over all the other communities.

At the beginning of this chapter stress was laid on the fact that every region receives a characteristic impress from the nature of the plant-communities inhabiting it, and that a knowledge of the latter is consequently of great importance in descriptive geography. The remark has also been made more than once that the particular conditions of soil and climate in a locality find expression in plant-communities, as it must be presumed that the species characteristic of each community can only grow in masses at places where the composition of the soil and the conditions of illumination, temperature, and humidity are in harmony with the specific organization as a whole. But if the local conditions of the ground and climate are reflected in the plant-communities, it is equally the case that the distribution of the plant-communities and formations constitutes an important and perhaps the only available basis for a division of the earth into natural floral areas. We proceed on the principle that every district possessing a series of plant-communities which are peculiar to itself is to be treated as a floral area, and that a limit to such area occurs at every place where the characteristic communities of a particular floral area are threatened with destruction, and, therefore, encounter the natural boundary of their range, where other communities better adapted to the altered external conditions make their appearance, and where there is consequently a change in the aspect of the whole landscape. This also supplies the scheme for a scientific geography of plants. Unfortunately we are still far from possessing any such science. We have only a

scanty knowledge of the plant-communities of Central and Northern Europe, and in many extensive tracts as good as nothing is known concerning the most important of all the data required for a demarcation of floral areas. There is nothing for it, therefore, for the present but to grope along with the help of the little that has been ascertained, and in the case of many districts to retain the demarcations laid down by earlier investigators, notwithstanding the fact that they are based upon altogether different foundations.

According to this system, the various Floras may be roughly distinguished as follows:—

1. Arctic Flora. The northern parts of Europe, Asia, and North America, extending southwards about as far as to the Arctic Circle.
2. Baltic Flora. Scandinavia, Great Britain, North-German Lowlands, Western Russia encroaching to the south on the Floras of the Mediterranean and Black Sea.
3. Flora of the Black Sea. South-eastern Europe, Asia Minor with the exception of its southern and western shores, the Caucasus, Kurdestan, Persia: environs of the Caspian Sea.
4. Mediterranean Flora. Shores of the Mediterranean: Southern Europe, the western and southern shores of Asia Minor. Coasts of Syria, Egypt, Tunis, and Algiers.
5. Atlantic Flora. Azores, Canary Islands, western shores of the Spanish Peninsula, Morocco.
6. Siberian Flora. The plain extending from the river Obi and its sources to the Stanovoi Mountains.
7. Kamschatkan Flora. North-east Asia as far south as the region of the Amur River.
8. Amur Flora. Amur district, Manchuria.
9. Chinese Flora. China, Japan, extending nearly as far south as the Tropic of Cancer.
10. Flora of Central Asia. Mongolia, Thibet, bounded to the west by the Steppe-region of the Sea of Aral, and to the south by the Hindu Kush and the Himalaya.
11. Flora of South Arabia and Mesopotamia. Northern shores of Somali, South Arabia, Mesopotamia; shores of the Persian Gulf.
12. Sahara Flora. The Sahara to about 15° N. Lat., Northern Arabia.
13. Soudanese Flora. Bounded on the north by the Sahara, on the south by 10° N. Lat., to the east by the mountainous region of Abyssinia.
14. Flora of Guinea. From 10° N. Lat. to 10° S. Lat., eastwards to 35° E. Long.
15. Zambesi Flora. From 10° S. Lat. to the Orange River on the south, and bounded to the east by the Drakenberg Mountains and Lake Nyassa.
16. Abyssinian Flora. Abyssinia and the mountains adjoining it on the south.
17. East African Flora. From the shores of the Indian Ocean to the East African Mountains, northwards as far as 8° N. Lat.
18. The Cape Flora. The south-western part of the Cape, bounded to the north by the Great Karroo Desert.
19. Madagascan Flora. Madagascar.
20. Indian Flora. Bounded to the west by the Indus, to the north by the Himalaya and the Yunnan mountains, and extending eastward as far as the Straits of Lomboc and Macassar.
21. Pacific Flora. Pacific Islands from the Moluccas to the Marquesas Islands on the one hand, and from the Sandwich Islands to New Zealand on the other.
22. Tasmanian Flora. Victoria, Tasmania, New South Wales, and adjoining regions.
23. Australian Flora. Interior and Western Australia.
24. Canadian Flora. Bounded to the north by the Arctic Flora, and reaching westward as far as the Rocky Mountains, and southward as far as the North American Lakes.
25. Columbian Flora. Bounded on the north by the Arctic Flora, on the east by the Rocky Mountains, on the south by 50° N. Lat.
26. Mississippi Flora. Extending northward to the Lake region, southward to Florida, exclusive of the southern third of that Peninsula, and bounded to the west by 95° W. Long.

27. Missouri Flora. Region of the Missouri River and of the high land between the Rocky Mountains and the Cascade Mountains.
28. Flora of the Pacific Slope. Coast region west of the Cascade Mountains, California.
29. Texas Flora. Arizona, Texas, North Mexico.
30. Mexican Flora. Mexico as far as Nicaragua.
31. Antilles Flora. The Antilles and the Bahamas, southern extremity of Florida.
32. Brazilian Flora. Bounded to the west by the Andes from the Gulf of Guayaquil to Tucuman, extending southward to 30° S. Lat.
33. South American Flora. Coast land west of the Andes and the part of South America between 30° and 50° S. Lat.
34. Magellan Flora. The extremity of S. America from 50° S. Lat., excluding the high mountains.
35. Antarctic Flora. Antarctic Islands, high mountains of the southern extremity of South America.

In this outline only a passing reference has been made to the Floras which at present occupy the higher regions of mountain chains, and which are restricted to comparatively small areas. Yet there is often far more difference between these and the Floras of the lower parts of the mountains and of the adjacent plains than there is between Floras which exist side by side in the lowlands, and are usually scattered over wide areas. Thus, for example, the Flora of the high mountains of Central Europe, commonly known as the Alpine Flora, differs so utterly from the Baltic Flora developed to the north of the Alps, and from the Mediterranean Flora flourishing to the south on the shores of the Mediterranean Sea, that it could not be classed either with the one or with the other. The same phenomenon is observed in other regions where lofty mountains occur, and, probably in addition to the thirty-five Floras above mentioned, as many more high-mountain Floras might be distinguished. The importance of these mountain Floras in relation to the formation of the Floras of the plains and to the general history of the plant-world will be set forth in the next section.

5. THE EXTINCTION OF SPECIES.

In the portion of this work which dealt with the origin of species, the view was taken that the new species which make their appearance in the course of ages are the products of cross-breeding between previously existent species. Valuable support is given to this opinion by facts relating to such genera as are represented in one district by a large number of species, and in another by a single species only. In many cases the wealth of forms comprised by a genus is prodigious. It is no easy matter to bring the numerous species of such a genus under review in a single series, because they are connected not only lineally, but also collaterally amongst themselves in all sorts of ways by intermediate forms. Within these generic spheres new forms continue to spring up in our time, and these are proved to be the results of crossings. For example, the multiplicity of forms included in the Bramble-genus (*Rubus*) is extremely great in Central Europe.

Botanists of the old school supposed the reason of this to be that the species of *Rubus* vary from some unknown cause—presumably from an intrinsic tendency in themselves. At the present day no intelligent observer doubts that many of the plants thus set down as the results of mere spontaneous variation are species which arose by inter-crossing in comparatively early times. Such inter-crossing was rendered possible by the fact that in the course of those displacements and alterations affecting floras, to which the present distribution of plants must be attributed, several species of *Rubus*, which had survived from previous periods, met and settled down together in Central Europe. On the coasts of Dalmatia and Greece, where only a single species, viz., *Rubus ulmifolius*, Schott (= *R. amœnus*, Portenschlag), established itself when the changes in question took place, there was no possibility of any multiplication of forms. From that solitary species sprang descendants which never changed; in other words, the specific marks of *Rubus ulmifolius* remained permanent in the above-mentioned parts of the Mediterranean floral area. The idea of the old school of Botanists was that this particular species of *Rubus* had no inclination to evolve new species; or, to use the more erudite but still less intelligible mode of expression, it was destitute of any tendency towards differentiation. The proper explanation of the fact is, however, much simpler and more natural. In the region where this particular species of *Rubus* is settled, there is no possibility of new species of that genus arising by means of inter-crossing. Perhaps some future displacements of floras will bring *Rubus ulmifolius* into proximity with other species of Bramble, and in that case it is sure to take part once more in the generation of new species. If, on the other hand, some event should cause the extermination of the entire Bramble-flora in the adjacent districts, and *Rubus ulmifolius* should remain isolated, no new species will spring from it any more than hitherto. A completely isolated species may continue to reproduce and multiply sexually and asexually for centuries without exhibiting any alteration, provided that the conditions of climate and soil are congenial to it, but it cannot take any part in the production of new species. If at length destruction befall such a species—a by no means impossible contingency, as one change of climate succeeds another, and causes fresh displacements of the limits of plant distribution—the event would connote the extinction of the whole genus of which this species was the sole surviving representative.

The result of comparative researches has been to show that the extinction of single species frequently occurs, whereas such groups of species as Botanists designate by the name of genera rarely die out. By far the greater proportion of the plants whose remains have been preserved from former periods in a fossil condition belong to genera which are represented by plants still living at the present day; only many of the extant representatives differ specifically from those which existed long ago. We conclude that the living types replace extinct ones and have entered upon their parts in life. It is also worthy of note that the fossil remains are often found at entirely different places from those inhabited by their nearest relatives in modern times.

The most striking examples of genera that have become extinct are afforded by the alliances to which the Club-moss and the Horse-tail respectively belong (see pp. 713 and 716). Those genera most exposed to the danger of extinction are such as are only represented by a single species (termed *monotypic* genera). This risk is intensified if the species in question only occurs in one district, as is the case, for instance, with *Welwitschia*. The genus *Rhodothamnus* of which only one species, *R. Chamæcistus*, lives at the present day, and the genus *Azalea* which is, so far as we know, represented by the species *A. procumbens* (*Loiseleuria procumbens*) alone should, on the other hand, have a better chance of escaping extinction. For the area of distribution of the former is broken into two sub-areas by the broad stretch of land reaching from the Eastern Alps to the Altai Mountains, whilst the *Azalea* grows not only on the high mountains of Central and Southern Europe but also in the Arctic regions, leaving a great space between the two areas uninhabited by its kind. Thus, presumably, even if such a species were to vanish entirely from one of its sub-areas of distribution in consequence of changes in climatic conditions it would still be represented by individuals growing at some spot which, being remote from that sub-area, would in all probability not have been affected by the alterations in question.

The number of species that have died out is extremely large. Every group of species which comprises both living and fossil members affords instructive examples in this connection. It is assumed that of species now living the endemic kinds have their existence most seriously menaced, or, in other words, are exposed to the most speedy extinction. If the restricted areas of the South-eastern Alps, where *Wulfenia Carinthiaca*, the most famous of the endemic species, is native, were to undergo a change of climate which no longer permitted the propagation of that species either by sexual or asexual methods, and at the same time rendered its migration impossible, it would be only a matter of time before *Wulfenia Carinthiaca* disappeared completely from the face of the earth. The genus *Wulfenia* would not, it is true, thereby become extinct, for a second species named *Wulfenia Amherstia* occurs in the Himalaya. But as this species, too, is endemic it might easily be overtaken by the same fate, and then the entire genus would have died out. It is, however, conceivable that the change of climate supposed to affect the South-eastern Alps, instead of causing the extinction of *Wulfenia Carinthiaca*, might result in the expansion of its area of distribution, and that no such hindrances to its migration as at present prevail should exist. The two species now inhabiting such widely remote districts might then conceivably come together and cross with one another, with the result that new species would be produced in the genus *Wulfenia*. It will be seen from these examples that one cannot be too cautious in dealing with assumptions concerning the future destinies of species. Many endemic species are probably doomed to extinction in the near future; but it is also not impossible that they may instead be called upon to play an important part in days to come.

An account has already been given (pp. 590, 592) of the manner in which nature affords compensation for the extinction of species, and how new species, the

products of crossing, take the place of the parent-stocks, so that the only remark that need be added here is that when such substitution is observed in the case of plants belonging to successive geological periods, it seemed as though a gradual re-casting or moulding of the species had taken place, and was regarded as a phenomenon determined by the direct effects of variations of climate until the time when the great importance of crossing in relation to the genesis of new species began to be recognized.

The partial extinction of a species, i.e. its disappearance from particular parts of its area of distribution, must be distinguished from complete extinction. Of the numerous instances of partial extinction within our knowledge some have been due to intentional or unintentional extermination by mankind, but the majority are cases where purely local extinction has resulted from natural causes independently of human influence. Reference has repeatedly been made in these pages to cases of plants which grow in the midst of now reigning floras and yet do not belong to them, and they have been likened to outposts left behind by former occupants of the soil, being apparently the remains of floras which formerly flourished on the areas in question, but which have been turned out and forced to take refuge in neighbouring regions. If their displacement were due to climatic vicissitudes it is conceivable that separate species or even entire communities may have been left behind here and there in especially favourable, though possibly very restricted habitats, and such isolated spots then seem as though they had been wrested from the main area of distribution which stretches over a wide expanse of country in the vicinity. Interesting examples of this are afforded by several species which are confined to isolated habitats in Carniola, of which the "Königsblume" (*Daphne Blagayana*) may be selected as a type. This plant grows on the slopes of some mountains in the neighbourhood of Laibach. Before the flora of the Balkan Peninsula had been accurately explored it was believed that this species of *Daphne* had no other habitat than that on the mountains above mentioned. More recent botanical researches have, however, revealed the fact that the main area of distribution of *Daphne Blagayana* is really in the Balkan Peninsula, in Bosnia and Servia, and that the habitat in Carniola is to that area as an island to the mainland. When one sees by what a small number of individuals, amounting to some thousands only, this curious plant is represented in Carniola, and how rare it is for even these to bring fruits to maturity owing to the fact that autogamy is impeded and that the supply of insect-visitors is insufficient, there is no escape from the conviction that a series of very severe winters would be enough to cause its complete extermination in this district. Under such circumstances its existence in the main area of distribution in the Balkan Peninsula might not be in any way imperilled, for it is not likely that the particular causes to which the extinction of the species in the small area in Carniola would be due would operate in all the habitats in the larger area, which is hundreds of kilometres away.

That such phenomena as have here been suggested as possible and even probable in the case of *Daphne Blagayana* do actually happen is evidenced by the plant-

species which in one district form a considerable part of the flora in possession at the present day, whilst in another floral area they are only found in the fossil state and under conditions which leave no doubt that they formerly lived there, but have long died out. *Rhododendron Ponticum*, for example, is an important constituent of the flora which now flourishes in the neighbourhood of the Black Sea, and is also found far to the west in an unrestricted area in the South of Spain at a great distance from the main area of distribution. It is encountered in the fossil state on the southern slopes of the Solstein chain in Tyrol in the upper strata of the so-called Höttinger Breccia. Thus this plant must have ranged formerly through Southern and Central Europe to 47° N. Lat. In the South of Spain it has survived on an isolated spot, whilst in the Northern Dolomites it has died out. A similar instance is offered by the case of several Juglandaceæ which form part of the woods of North America at the present day, and are only found as fossils in Europe.

The results of researches into the history of the separate species constitute the foundation for a history of the entire plant-world. Formerly the discovery of fossil-remains was looked upon as the most important means of eliciting that history, but now the distribution of living plants is taken into account, and the significance of such circumstances as the presence of endemic species and of species isolated in the midst of a foreign flora is fully recognized. A study of endemic species and of outlying sub-areas of distribution yields in particular most valuable information concerning the conditions which prevailed in the earliest periods of the earth's history. The most noteworthy inference made in this connection is that over a great part of central Europe since the last ice-age a flora was evolved which was only capable of existing under the influence of a continental climate of far greater warmth than now prevails. For instance, plants whose main areas of distribution at the present day are in the steppes of Southern Russia, in the Crimea, and in the valleys of the Caucasus are found growing, sometimes alone sometimes in communities, in Central Europe, in the region of the Baltic Flora, on warm, sunny mountain-slopes, and in sequestered glens far from the modern lines of traffic, and under circumstances which exclude all possibility of an immigration having taken place in recent times. Such exceptional habitats of the plants in question occur on hot, sombre rocks of serpentine in Lower Austria, on terraces of loess and mountains of schist, situated on the eastern border of the Böhmer Wald and the Mährische Gebirge, in the interior of Bohemia and westwards on scattered spots as far as the Harz Mountains, and, again, in the region of the Northern and Central Alps, from the Wiener Becken to the Lake of Constance, as, for example, far away in the highest parts of the valleys of the Adige and the Inn. These plants may be for the most part described as Steppe-plants, and if, as can no longer be doubted, they are the remains of a flora which once ranged in Central Europe as far as the Harz Mountains, we may conclude that just before the establishment of the present climatic conditions which suit the Baltic Flora, a Steppe-climate prevailed over the area referred to, and the summer was hot and dry. There is good ground for supposing that the various animals belonging to the Steppe-fauna (Steppe-antelope, Steppe-marmot,

&c., cf. p. 462) which have been discovered in Central Germany are relics of this period, that they lived with the Steppe-plants and withdrew eastward at the same time in consequence of the change of climate. It is difficult to say when these changes took place in Central Europe, but this much is certain, that the Steppe-climate prevailed for an exceedingly long time, that the alteration of that climate into the kind which now prevails took place quite gradually, and that accordingly the migration of the Steppe-flora and fauna into the region now occupied by them was performed very slowly.

As the very thing which is injurious to the members of one flora is usually beneficial to those of a neighbouring flora the migrations of plants really take the form of displacements of the boundaries of distribution. No sooner do the species of one flora withdraw to escape a climate that has become unsuitable to them than their place is taken by those members of the neighbouring flora which are adapted to the new climate. In the case above referred to, an immigration of such members of the Baltic flora as prefer a comparatively cool, moist summer would inevitably take place synchronously with the retreat of the Steppe-plants. As regards the situation of the previous home of these Baltic plants there can be no doubt. They came from adjacent regions where the climatic conditions congenial to them already existed, that is to say, from parts then forming the coast and from those mountains which had not been ascended by the Steppe-flora. In advancing inland from the coast and descending from the mountains these plants were only in a measure retracing their steps to places where they formerly occupied the ground, and from which they had been ousted by the Steppe-plants. In other words, before the reign of the Steppe-flora of the Black Sea was established in the valleys and lowlands of Central Europe another flora lived there which closely resembled that which we now call the Baltic flora. No approximate estimate can be given of the length of time, previous to the immigration of Steppe-plants, during which the Baltic flora was in possession of the tract of country thus destined to fall a second time under its dominion; but it has been established beyond question that it was not as yet upon the scene at the period of the greatest prevalence of glaciers in Central Europe, and that its first immigration cannot have taken place until after the retreat of the large glaciers.

At the epoch when glaciers attained their maximum dimensions the places now covered by the forests of Pines and Firs, which are so characteristic of the Baltic flora, and by vast scrubs of heaths and broom, were occupied by low Alpine plants which may for the sake of brevity be spoken of collectively as an Alpine Flora. Formerly botanists were of opinion that this wonderful flora spread southwards like a flowing stream from the Arctic Regions at the epoch in question. This view is not, however, in harmony with more recent discoveries. It was based on the erroneous assumption that the flora of the Arctic Regions was the same as that of the alpine regions of Central and Southern Europe. When we compare the Arctic and the Alpine floras merely by means of their records in books and herbaria, it does indeed look as if the closest relationship existed between the two; for a not inconsiderable

number of species belong to both floras, and are only lacking at the present day in the broad tract interposed between the Alps and the Arctic Regions. But of these species common to both floras the majority are distinguished in the Alps by their rarity, and only grow on particular spots here and there on black earth or peat, or close to cold springs. Many must be the botanists who have rambled year after year over the Alps collecting flowers without ever coming across such species as *Saxifraga cernua*, *Betula nana*, *Juncus arcticus*, and *Juncus castaneus*, which are common in arctic areas of vegetation but very rare in the Alps, though they may have climbed all the summits high and low, and searched the most sequestered valleys, and, moreover, may possess a thorough knowledge of Alpine vegetation. Similarly, when a Botanist, who has acquired on the spot an accurate knowledge of the Arctic Flora, pays his first visit to the Alps an entirely new world meets his gaze. Not only is the number of species indigenous to alpine regions much larger than that found in the extreme north, but the two floras differ widely in their composition. The very species which are of most common occurrence in the Alps, and which constitute the ground-work of the communities characteristic of that region, are alien to the Arctic Flora. Such are the extensive meadows of Grasses and Sedges, the low-growing forests of Mountain Pines, Alders, and Dwarf Medlars, the scrub of Alpine Roses (*Rhododendrons*), and the carpet of prostrate woody plants (*Rhamnus pumila*, *Daphne striata*, *Salix retusa*, *S. Jacquiniiana*), besides many other species which are peculiarly adapted to a substratum of rock or debris, and constitute one of the chief glories of the Alps. To this category we must also add the particular plants which, next to the Alpine Roses, are the most commonly recognized representatives of the Alpine flora, viz. *Valeriana celtica*, *Meum Mutellina*, *Primula Auricula*, *Artemisia Mutellina*, *Gnaphalium Leontopodium* (the Edelweiss). The alpine species of more than 50 genera do not grow at all in the arctic regions, and in the case of many other genera, though both districts possess a few of the species in common, it is just those which are peculiarly characteristic of the Alpine Flora that one seeks for in vain in the extreme north. It would thus be absurd to suppose that such a flora has migrated from the arctic regions to the Alps, and there is much more reason for concluding that the scanty flora of the arctic region was in part derived from the high mountain areas of more southern latitudes.

Researches into the subject of the distribution of Alpine species and of the genera to which they belong have revealed the fact that some alpine plants occur also in the higher parts of the Carpathians, in the Caucasus, in the Altai Mountains, and even in the Himalayas, whilst others are found in the Abruzzi and the Balkans, and upon these data might be based the hypothesis that the alpine flora was derived from the east and south, and migrated in the Diluvial Period from the Himalayas, the Caucasus or the Abruzzi to the Eastern Alps. But the same facts might equally well lead any one who made a similar investigation of the Alpine flora of the Caucasus or the Himalayas to infer that the plants in question had travelled thither from the Alps. I believe that all such hypotheses involve one in a circle, and bring one no nearer to the goal. If we wish to solve the question as to what was the place of origin of

the plants which took possession of the ground whence glaciers and snow-fields retreated after the great diluvial ice-age, it is not necessary to look so far afield. We need only bear in mind that in the period preceding that in which the glaciers attained their maximum size in the higher mountains of the Alps, a flora must have existed there, and that this flora would have been forced down from the higher to the lower parts of the mountains and into the sub-alpine regions by the climatic vicissitudes which occasioned the glacial condition. In the Tertiary Period the diminution of temperature accompanying an increase of elevation was doubtless not materially different from what it is at the present day. The general relief of the Alps was the same in the Miocene period as it is now; also in the Eocene period, and even in the more recent portions of the Cretaceous period the Alps were already a considerable mountain region including probably some high peaks. The Limestone Alps had their fjords, and the Central Alps were deeply cut into by cross valleys. The vegetation clothing the lower slopes could not be the same as that of the higher regions, but, as at the present day, there must have been several floras situated one above the other. Glaciers must have existed in a latitude of from 46° to 48° at an elevation of 3000 metres in the highest depressions in the mountains, and that at so small a distance as 50 kilometres from the sea-coast, and subject to a yearly variation in temperature of 8° – 10° Centigrade; and even though woods of Laurels and Myrtles flourished in the latter part of the Miocene period of South-eastern Europe on the spurs of the Alps on the margin of the Wiener Becken, that does not exclude the possibility of an Alpine flora having developed simultaneously on the snow mountains of that neighbourhood, and on the Rax-alp and the Hochschwab (in the mountains of Northern Styria). The Carniola Schneeberg to the north of the Gulf of Fiume affords quite sufficient proof that even a mountain of only 1800 metres may harbour Laurels and Evergreen Oaks at its feet, whilst alpine vegetation flourishes on its summits.

The fossil remains of the Miocene flora that are known to us were all discovered in lowland places, and they therefore only represent the plants belonging to gently undulating ground or growing on quite low mountains, and no inferences can be drawn from them as to the nature of the vegetation of the higher regions. I think that we may fairly deduce the conclusion that the majority of the alpine species lived on the heights of the Alps as long ago as in the Miocene period, and that the Alpine Flora though repeatedly forced down to lower levels, always returned again. As a matter of course the composition of the Alpine Flora underwent many changes in the process. The partial intermixture of species belonging to adjacent floras with the alpine species, which must inevitably have taken place in the course of these displacements, led to inter-crossing and consequently to the production of new species, whereof a proportion were no doubt adapted to the altered climatic conditions and capable of preserving their existence. On the other hand, many of the species which already inhabited the Alps in the Miocene Period have died out there or have only survived at isolated spots of limited area, as, for instance, *Wulfenia Carinthiaca* (see p. 882) in Carinthia, and *Rhizobotrya alpina* on the

Fassa Alps in Tyrol. This holds especially in the case of the majority of those species which belong both to the present Arctic Flora and to the present Alpine Flora. Let us suppose the Alpine Flora driven as far as the North of Germany at the time of the greatest distribution of the diluvial glaciers. Extensive glaciers had also advanced far to the south from the north, and had caused a displacement of the flora indigenous to the Scandinavian Mountains in the Tertiary period as far to the south as Northern Germany. Thus the floras of the north and of the Alps must have met there, and when later the climate again became milder a retreat of the immigrants took place on the one side towards the north, on the other side towards the Alps. On this occasion some species which previously did not occur in the Scandinavian Mountains travelled northward, and some hitherto unknown in the Alps travelled into the Alps. To that epoch must be ascribed the introduction into Germany of several Arctic species, e.g. *Alsine stricta*, *Saxifraga*, *Hirculus*, *Pedicularis Scepttrum*, *Statice purpurea*, *Salix depressa*, *Betula humilis*, and *Juncus stygius*—which then became dispersed over the low lands lying at the foot of the Alps in Salzburg and Bavaria, though they did not reach the Alpine region, but remained behind on the northern border of the mountain area.

The remarkable relations above referred to as existing between the Alpine flora of the Alps and those of the Carpathians, the Caucasus, the Altai, and the Himalayas, and also those of the Pyrenees, the Abruzzi, the Dinaric Mountains, and the Balkans cannot be explained by what took place in the Diluvial period. It has been ascertained by geologists that the first glaciation of the Alps was not more recent than, but was possibly even prior to, the third stage of the Miocene Period in the south-east of Europe, and that during that epoch there could have been no connection between the high mountain flora of the Alps proper and those of the Carpathians and the Balkans, not to speak of the mountains lying further to the east or south, even though the Alpine flora may have descended to a much lower level on the eastern side. The high mountain floras have hardly met one another either in the direction of east and west, or in that of north and south. If, therefore, in the Alps, after the retreat of the glaciers, other species joined forces with those belonging to the Alpine flora which returned once more to higher regions, these were species belonging rather to hilly lowlands. Many such species are able to endure the alpine climate without being injured, and they are represented even at the present day by large numbers of individual plants both in the lowest parts of the valleys and on the heights of the Alps. Thus *Erica carnea*, *Globularia cordifolia*, and *Biscutella laevigata* may be traced from the shores of the Adriatic and the banks of Lake Garda, and from the less lofty heights on the border of the Wiener Becken up into the alpine region, and may be looked upon as representatives of the plants which naturalized themselves in that region after the last diluvial ice-age.

If the kinship of the floras growing on the crests and shoulders of the high mountain chains which succeed one another from west to east and from north to south is not explicable from what took place in the Diluvial period, we must go back to an earlier time when either the mountain ranges now separated from one

another were continuous or an intermingling and exchange of species were rendered possible by floral displacements occasioned by vicissitudes of climate. Before the influx of the first Miocene sea through Servia into Hungary and Austria, the Bakonyer Wald were joined to the Southern Limestone Alps; peaks of the height of the Grossglockner lifted their heads where now only low crests surmount the deposits of the Miocene sea, and those lofty peaks were no doubt clothed with an alpine flora. Similarly there was then no lack of high mountains covered with alpine vegetation between the Alps and the Carpathians. Geological information of this character is certainly of great value when it is a question of explaining the close relationships existing between the alpine flora of the Eastern Alps and that of the Carpathians; but the presence of such mountains before the Miocene Period does not suffice to explain the uniformity of the alpine species, the affinity existing between the natural groups to which they belong, and the curious overlapping and interlacing of the boundaries of their areas of distribution on the high mountain ranges which run from west to east and from north to south. There must also have been at that time some impelling cause to account for the intermingling of the floras in question, and for the displacement of their boundaries. The only phenomena which can be presumed to meet the case are alterations of climate of so drastic a nature as to cause a simultaneous descent—and subsequently again a simultaneous return—of the alpine species belonging to the two mountain-chains. These climatic changes must have been the same as those which culminated in the successive formation and advance and subsequent retreat of glaciers in those of the mountains which were lofty enough and of suitable conformation.

In the most widely different strata of our earth's crust, deposits occur which are to all appearance moraine-débris, and are looked upon as glacial deposits by every unbiassed geologist. There is, therefore, good ground for the hypothesis that an alternate advance and retrogression of glaciers has taken place not only in the Diluvial period, but also in the Tertiary period, and generally in all the periods distinguished by geologists. In my opinion the periodical return of a cold, wet climate, manifested in suitable localities by an increase of glaciers, has everywhere and in every age been the cause of migrations, and indirectly of inter-crossing, the formation of new species and the extinction of old ones; and I think that, so far as it goes, it accounts for the displacements, modifications of type, and other changes undergone by the various floras in successive geological periods. Mountains have played an important part in this history. They are able to produce an inexhaustible supply of plants ever ready to colonize less elevated regions down to the plains below, for their slopes are the camping-ground of plants adapted to every kind of climate. When a slight diminution of temperature occurs, the denizens of the lower forest region spread over the plains; a more considerable access of cold impels the plants of the upper forest-region to become the invaders, and so on until it comes to the turn of the vegetation which subsists close to the limit of perpetual snow, where the snow vanishes for only about 50 days each year. And, just as on occasion of a fall in temperature, the plants gradually descend the mountain sides and disperse them-

selves over the lowlands, so also if the temperature rises they are able to retire to the heights again. No more need be said to show that the advance and retreat of vegetation has taken place, and does still take place, *pari passu* with the growth and melting away of glaciers.

Very various notions concerning the cause of the periodical return of an ice-age have prevailed from time to time. Several prominent experts of the present day believe that alterations in the eccentricity of the earth's orbit are the cause of the phenomenon. When the eccentricity increases the earth's surface is considerably cooled, and as the eccentricity diminishes the heat increases. A period of great eccentricity must have begun about 240,000 years before our era and have lasted 16,000 years. Similarly the great eccentricity which existed 850,000 and 2,500,000 years before our era must have brought about repeated glaciation. By others an alteration of the position of the pole is considered to be the cause of the phenomenon in question. Much may no doubt be urged against this explanation, but several phenomena in the plant-world are more easily reconciled with it than with any other. One example of these is the existence of lofty plants with large foliage in the Arctic region during the Miocene, Cretaceous, and Carboniferous periods, as is proved by the discovery of numbers of fossil remains. In the Miocene and Cretaceous periods, Tulip-trees, Magnolias, Limes, Planes, Bread-fruit trees, and Water-lilies flourished in North Greenland, Grinnell Land, Iceland, and Spitzbergen. None of these plants can live there now, for the two following reasons. Firstly, the conditions in respect of solar illumination which obtain there would not permit of their healthy development; and, secondly, there is not sufficient warmth to enable them to grow hardily. Since the most eminent geologists of the day have declared against the idea of the interior of the earth being in a fiery, molten condition it will not do to attribute to that source the high temperature necessary for great Planes, Magnolias, and Bread-fruit trees to flourish in such high latitudes. On the other hand, the presence of large-leaved Angiospermous trees in North Greenland, Grinnell Land, Iceland, and Spitzbergen would be satisfactorily explained if it were assumed that the spot which now forms the North Pole—and with it the whole region now called Arctic—then occupied a different position relatively to the earth's orbit, and consequently received a different amount of light and heat.

As regards the history of plants prior to the Eocene and Cretaceous periods no data are afforded by the investigation of the distribution of living plants, and we are thrown back on the fossil remains derived from those older periods. These are unfortunately comparatively scanty, and they no doubt represent but a small proportion of the species which lived before the Cretaceous period. Two conclusions may, however, clearly be drawn from these remains, viz.: firstly, that no single main division existed at that time which is not still represented at the present day; and, secondly, that some very conspicuous genera of particular groups have died out and been replaced by other genera of the same groups. Specially noticeable in this connection are the tree Club-mosses of the Carboniferous period and the Calamites, species of Horse-tail which must have formed extensive forests in the Carboniferous

periods. The occurrence of these curious *Calamites* of the Carboniferous period strikes one most when they are found in localities where the ground is now occupied by low herbs, Mosses, and Lichens, and is covered with snow for three-quarters of each year, as is the case in Nova Zembla, Spitzbergen, and Bear Island. In the region of the Alps, too, we encounter spots where this surprising phenomenon is again presented. One of the most remarkable is the upland valley in the Tyrol known as the Gschnitzthal. I have for many years passed the summer months in that valley, and it is there that the greater part of this Natural History of Plants has been written. The house which I occupy stands at an elevation of 1215 metres above the sea-level, and is built upon a diluvial moraine in the middle of the valley. The glaciers which made the moraine have retreated 15 kilometres, and now form the head of the valley. On its débris, dating from the Diluvial period, now grow Firs and Pines, Junipers and Heather, all of which are members of the Baltic Flora. Six hundred metres higher up, arboreal growth ceases and the sides and shoulders of the mountains are clothed alternately with extensive Alpine meadows and scrubs of Alpine *Rhododendrons* and carpets composed of *Azalea procumbens* and of creeping Dwarf Willows. On the Steinacherjoch, one of the neighbouring ridges, at an elevation of 2200 metres above the sea-level, the ground consists of dark fissured slabs of schist, covered with Lichens and Mosses, and here and there overgrown also by Saxifrages and Primulas. If one of these slabs be split open, the inside is found to bear the impress of *Calamites* and giant Ferns of the Carboniferous period. What an endless series of changes must the vegetation have undergone since the time when groves of *Calamites* flourished here. Over and over again has the place wherein they now repose been turned into the bed of a sea wherein were constructed the coral reefs which now surmount the dark ancient schist in the form of pale grey dolomitic peaks. Forest after forest of Coniferous or of Angiospermous trees has spread its shade over the spot for a time and then passed away. Huge tracts of ice have filled the entire valley, and upon the débris of the moraines deposited by the glaciers in their progress now rests a carpet of Primulas, Saxifrages, and Gentians.

“Ebbe und Flut—so wechselt der Tod und das blühende Leben,
Blumen pflanzt die Zeit auf das vergessene Grab.”

GLOSSARY.

Abscission, the natural cutting off of members by means of a layer of separation.

Absciss-layer, a layer of separation. See above.

Acaulescent, stemless, or apparently so.

Accrescent, applied to the parts connected with the flower, as the calyx, &c., which increase in size after flowering.

Acerosæ, Alex. Braun's term for the Coniferae.

Achene, a dry indehiscent 1-celled 1-seeded fruit.

Achlamydeous, used of flowering plants which have no calyx or corolla.

Acicular, bristle- or needle-shaped.

Acotyledones, old term (De Jussieu) for non-flowering plants.

Acramphibrya, Endlicher's term for Dicotyledons and Gymnosperms, regarded as plants growing both at the apex and at the sides.

Acrobrya, Endlicher's term for plants growing at the apex only.

Acrocarpous, said of Mosses which produce their fruit (sporangia) at the tips of their shoots.

Acrodromous. See vol. i. p. 633, fig. 150¹.

Actinomorphic, applied to flowers which may be divided vertically into similar halves through two or more planes.

Aculei, slender, rigid prickles, growing from the bark, as in the Rose.

Adhesion, the union of parts normally separate.

Adnate, congenitally united or grown together.

Adventitious buds, buds produced out of their regular order.

Æcidium, in Uredineæ, a cup-like collection of spores which are budded off from the base of the cup.

Æstivation, the folding of the parts of a flower in the bud.

Aggregate fruit, a fruit formed by the crowding together of distinct carpels; the product of a single gynoecium when that gynoecium is apocarpous.

Aggregation, the condition of extreme activity of the stalk-cells of the tentacles of a *Drosera*-leaf, resulting from mechanical or chemical stimulation.

Akinetes, in Green Algae, are single cells of the thallus, whose original walls thicken, and which separate from the rest of the thallus; they correspond to the chlamydo-spores of Fungi.

Alæ, descriptive term applied to the two lateral members or wings of a papilionaceous corolla.

Albumen, any form of nutritive matter stored within the seed and about the embryo.

Albuminous, containing albumen, as in the seeds of grain, Palms, &c.

Aleurone-grains, grains of nitrogenous food-material frequently stored in the reserve-tissues of seeds.

Alga, a chlorophyll-containing member of the Thallophyta; one of the plants, the best known of which are called Sea-weeds.

Alliance, a group of allied families or orders.

Amentaceous, having amenta or catkins; consisting of or resembling a catkin.

Amentum, a catkin. See *Catkin*.

Amœboid movements, constant changes of shape resembling those of the "Proteus animalcule" *Amœba*.

Amphibious, said of plants such as can live either in the water or in the air.

Amphibrya, Endlicher's term for the Monocotyledons.

Amphicarpium, an archegonium when it persists, after fertilization, as a fruit envelope.

Amphigastria, in Liverworts: certain small scales or leaves on the ventral side of the oöphyte generation.

Amphigonium, used sometimes by Kerner as a synonym for archegonium.

Amplexicaul, nearly surrounding or clasping the stem: used of the leaf base in certain cases.

Amylum, starch.

Anaphyte, an old term of the nature-philosophers by which the potential independence of every branch or shoot was indicated.

Anastomose, to inoculate or run into each other; to communicate with each other like arteries and veins.

Anatomy, the intimate structure of plants.

Anatropous, said of that form of ovule in which, although the nucellus is straight, the micropyle is bent down to the point of attachment of the funicle, and in which the body of the ovule is united to the funicle, which latter structure is known as the raphe.

Andrœcium, the collective term for the stamens of a flower.

Androgonidia, the cells which in *Volvox* give rise to spermatozooids.

Androspores, name given to the particular zoospores which in *Edogonium* give rise to miniature plants, termed dwarf-males.

Anemophilous, applied to flowers whose pollen is conveyed by the agency of wind; having flowers fertilized by wind-borne pollen.

Animalcule, a vague term applied to small motile organisms in water.

Anisogametes, sexual cells, which show a differentiation into male and female.

Annulus, (1) in *Agarics*: the ring which often remains round the stalk (stipe), and was originally attached to the edge of the pileus; the remains of the *velum parziale*; (2) in the Moss-capsule: the ring of cells which brings about the throwing-off of the operculum; (3) in the Fern-sporangium: a conspicuous row of cells running vertically, obliquely, &c., around the sporangium, by the contraction of which dehiscence takes place.

Anophyta, Endlicher's term for the Muscineæ.

- Anther**, the polliferous part of a stamen; the sac or cavity in which the pollen is contained.
- Antheridium**, a male sexual organ, usually producing motile spermatozooids.
- Anthocyanin**, a purple sap-pigment frequent in foliage and flowers.
- Antholysis**, literally a "loosened" flower, i.e. a flower in which the various parts have become more or less foliaceous, and from which inferences can be drawn as to the morphological nature of the component parts.
- Anthophyta**, Alex. Braun's name for the Phanerogamia.
- Anthoxanthin**, the yellow pigment of flowers and fruits.
- Antipodal cells**, a group of three cells at the chalazal end of the embryo-sac of Angiosperms.
- Apetalæ**, Dicotyledons destitute of a corolla.
- Aplanospore**, a non-motile asexual reproductive cell of the Green Algae.
- Apocarpous**, said when the carpels of a gynoecium are separate.
- Apophysis**, a swelling under the base of the theca in some Mosses.
- Apothecium**, the disc-like receptacle of an Ascomycetous Fungus.
- Arbor**, a tree.
- Arbuscula**, a little or dwarf tree.
- Archegonium**, in the higher Cryptogams the flask-shaped female sexual organ with neck and venter, the latter containing an egg-cell, the former canal-cells.
- Archivesporium**, a cell or group of cells from which spore mother-cells are produced.
- Archichlamydeæ**, a large group of Dicotyledons, including the old groups Polypetalæ and Incomplete.
- Areolated**, marked with little areas; divided into small areas by intersecting lines.
- Aril**, an investment to a seed which arises after fertilization. It is usually succulent.
- Arthrospore**, a form of spore produced in the Schizomycetes by the segmentation of the tubes into cells.
- Arundinaceæ**, reed-like.
- Ascidiform**, like a pitcher; pitcher-shaped.
- Ascidium**, a pitcher; an appendage somewhat resembling a pitcher. See *Pitcher*.
- Ascus**, a form of sporangium characteristic of certain Fungi. It is generally tubular and contains eight spores, the ascospores.
- Ash**, the inorganic residue which is left after a plant has been burned.
- Assimilation**, as used here, the building of a plant-substance from the nutriment of the environment. Often restricted to the manufacture of carbo-hydrate from carbonic acid and water.
- Asyngamic**, used of plants which are prevented from intercrossing by the fact of their non-simultaneous periods of flowering. Nearly related species can thus inhabit the same spot without hybrids ever being formed.
- "Attire"**, an archaic term, applied by Grew to the stamens.
- Auricle**, an ear-shaped appendage.
- Autogamy**, self-pollination, ultimately self-fertilization.
- Autonomous movements**, spontaneous; originating from inherent tendency.
- Auxospore**, the reproductive cell of a Diatom. See vol. ii. p. 626.
- Awn**, a bristle-like appendage, especially in the glumes of Grasses.
- Axis**, essentially the stem. The root is also an axis.
- Azygospore**, term given to the "zygospore" when it is formed parthenogenetically with conjugation.
- Bacterium**, one of the micro-organisms concerned in putrefaction: a term rather widely applied to any member of the Schizomycetes.
- Barba**, the retrorse appendages of bristles, or the teeth on leaf-margins.
- Bark**, the usually hard outer investment of a perennial stem (or root) which has arisen in connection with a cork-cambium; actually it includes the products of the cork-cambium and whatsoever is external to it.
- Basidium**, a cell from which spores or conidia are produced by a process of abstriction.
- Bast**, inner bark; a special tissue: *soft-bast*, the phloem—includes sieve-tubes and other non-hardened phloem-elements; *hard-bast*, the thickened prosenchymatous elements or bast-fibres.
- Bastard**, a term sometimes given to a hybrid.
- Bedeguar**, name given to the mossy red galls on the common Wild Rose.
- Berry**, a fruit the whole pericarp of which is succulent.
- Bilabiate**, two-lipped.
- Bizzaria**, a fruit, part Orange, part Citron. See vol. ii. p. 569.
- Blending**, a name given to a hybrid arising by the crossing of "races".
- Blossom**, cf. vol. ii. p. 71.
- Brachydromous**, used of leaf-veins. See vol. i. p. 630.
- Bract**, a leaf subtending a flower.
- Bract-scale**, the lower member of the duplex scale of the female cone of Pine, Fir, &c.
- Break back**, a term used by gardeners to convey the idea of reversion. Thus flowers break back or revert to an ancestral type.
- Bud**, the as yet unexpanded rudiment of a shoot; it comprehends both axial and foliar portions.
- Bulb** (bulbus), a bud consisting of an abbreviated axis with fleshy scale-leaves in which food-material is stored. Usually subterranean.
- Bulbil**, a deciduous bud, usually formed on an aerial part of a plant. Occasionally used for a little bulb.
- Callus**, the healing tissue which closes up the wounds of plants. The same term is given to a mucilaginous substance which arises on the sieve-plates of the sieve-tubes, closing them. The latter is of course quite a different structure, and to distinguish it from the former may be called *callose*.
- Calyptra**, the hood which is raised up on the sporogonium of a Moss. It is the ruptured upper portion of the archegonium.
- Calyx**, the outer whorl of the perianth, consisting of sepals.
- Cambiform cells**, cells resembling cambium cells; thin-walled, tapering cells found in the phloem accompanying the sieve-tubes, companion-cells, and bast-fibres.
- Cambium**, a layer of tissue formed between the wood and the bark, and consisting partly of nascent wood, partly of nascent bark.

- Campylodromous**, applied to the manner in which veins are distributed. See vol. i. p. 633, fig. 150².
- Campylotropous**, used of an ovule or seed in which the nucellus, with its integuments, is bent so that the apex is brought near to the point of attachment.
- Canker**, a vague term applied to the disease or Fungus which attacks plants and causes slow decay.
- Capillitium**, the thread-like fibres, often united into a reticulum, which are developed within the spores of Myxomycetes and many Gasteromycetes.
- Capitulum**, a head or globular cluster of sessile flowers.
- Caprification**, the custom of hanging branches of the wild Fig in the cultivated trees so as to ensure pollination by means of the gall-insects thus introduced.
- Caprificus**, the uncultivated male form of the common Fig.
- Capsule**, a dry, dehiscent fruit.
- Carobe di Giude**, Turpentine Gall-apple, produced on Pistacia Lentiscus by a Pemphigus.
- Carpel**, a single-celled ovary or seed-vessel, or a single cell of an ovary or seed-vessel together with what belongs to that cell; it may be regarded as a modified leaf.
- Carpium**, or **Carp**, the oogonium modified by fertilization, which remains as an envelope around the embryo. Cf. vol. ii. p. 47.
- Carpo-ascl**, the more complex Ascomycetous Fungi—all except the Exoascaceae.
- Carpophylla**, the carpels.
- Caruncle**, a localized outgrowth of the seed-coat; a sort of aril.
- Caryophyllaceous**, appertaining to the Pink family.
- Caryopsis**, an indehiscent one-seeded fruit, in which the thin seed-coat adheres to the pericarp, as in all cereal grains.
- Catapult-fruits**, fruits in which the dispersal of the seeds or fruit-segments is due to the elastic reaction of the resilient peduncles or pedicels.
- Catkin**, a pendulous inflorescence bearing flowers of one sex only; an amentum.
- Caudex**, a trunk or unbranched stem.
- Caudex columnaris**, an erect columnar stem, as in Palm-trees.
- Cauliscent**, having an obvious stem rising above the ground.
- Cauline**, appertaining to the stem.
- Caulis**, the stem or stalk.
- Caulis herbaceus**, a herbaceous stem.
- Caulis suffruticosus**, a suffruticose stem; the stem of an under-shrub.
- Caulome**, a stem-structure, or the stem-like portion of a plant.
- Cecidium**, a gall or hypertrophy on a plant-member, due to the stimulating action of an insect or Fungus.
- Cell**, the structural unit in the formation of plants; one of the individualized portions of which plants are built up.
- Cell-membrane**, the cell-wall.
- Cell-plate**, used here of aggregates of cells in one plane.
- Cell-sap**, the watery fluid contained in a cell.
- Cellular**, consisting of cells. Sometimes used of plants which are destitute of vessels.
- Cellulose**, a carbo-hydrate of which cell-membranes are composed; the essential constituent of cell-walls.
- Centrifugal**, a term applied to such inflorescences as develop from the centre outwards.
- Centripetal**, a term applied to such inflorescences as develop from without inwards.
- Cephalonion gall**, a sac-like gall joined to the leaf by a narrow neck.
- Ceratonion gall**, a hollow, thick-walled, horn-like gall, belonging to the series of Mantle-galls.
- Chalaza**, the part of an ovule where nucellus and integuments cohere; the base of the nucellus.
- Chalazogamic**, applied to fertilization in flowering plants via the chalaza and not by the micropyle, e.g. in the Hazel.
- Chlamydospore**, the reproductive organ in some Fungi.
- Chloranth**, the production of green flowers; a supposed reversion of floral structures to a primitive foliar condition.
- Chlorenchyma**, a term sometimes given to a green, chlorophyll-containing tissue.
- Chlorophyll**, the ordinary green pigment of plants which is the agent in the process of carbon assimilation.
- Chlorophyll-corpuscles**, protoplasmic bodies distinct from, yet imbedded in, the general cell-protoplasm of the green parts of plants. The chlorophyll is restricted to these corpuscles.
- Chromatophore**, a general term for any protoplasmic body containing a pigment. Chlorophyll-corpuscles are chromatophores.
- Chromosomes**. See *Fibrils*.
- Cilia**, delicate protoplasmic filaments serving as organs of locomotion, as in zoospores, &c.
- Cincinnus**, a form of cymose inflorescence, a one-sided cyme.
- Cirrh**, a term for stem-tendrils, i.e. branch-tendrils and flower-stalk tendrils.
- Cirrh**, a projecting or excurrent midrib, modified as a tendril.
- Cirrh**, a leaf modified as a tendril.
- Cirrh**, a flower-stalk modified as a tendril.
- Cirrh**, a petiole or leaf-stalk modified as a tendril.
- Cirrh**, a root modified as a tendril.
- Cirrh**, a tendril which is a modified branch.
- Cirrh**, a tendril which is a metamorphosed stipule.
- Cladodes**, leaf-like branches. See *Phylloclade*.
- Clamp-cells**, here used for the papilla-like cells by which an epiphytic root adheres to the substratum.
- Class**, the highest grade or division of plants in the system of Linnæus. In our system a class is subordinate to a phylum, and the classes are subdivided into alliances.
- Clavate**, club-shaped.
- Claw**, a name given to the stalk of a petal.
- Cleistogamic**, -ous, a term applied to the inconspicuous flowers produced by many plants. These flowers do not open, and are self-pollinated (autogamous).
- Cob**, a term applied to the spike on which Maize grows.
- Cœnobe**, or **Cœnobium**, a colony of separate organisms united by a common investment, e.g. Volvox.
- Coherent**, used of the union of similar members.
- Cohort**, a group of families or orders which are nearly related to one another; is used here as synonymous with Alliance.

- Collective fruit**, a fruit in which the products of a number of *separate* flowers become so crowded together as to appear as though they had arisen from a single flower, as the Pine-apple. Cf. *Aggregate fruit*.
- Collenchyma**, a living tissue, consisting of prism-shaped cells whose angles are much thickened. It is a form of mechanical tissue.
- Colony**. See vol. i. p. 585.
- Columella**, in *Muscineae*, the sterile tissue in the centre of the sporogonium around which the spore-layer is formed.
- Column**, the body formed as a result of fusion of stamens with style, as in *Orchid* flowers.
- Conceptacle**, the inclosing cavity in which the sexual organs are produced in the *Fucaceae*.
- Cone**, the aggregate of crowded scales which bear ovules or pollen-sacs in the *Gymnosperms*; applied also to the sporangiferous branches in many *Vascular Cryptogams*.
- Conidium**, in *Fungi*, a propagative asexual body.
- Conifer**, a plant producing cones; one of the *Coniferae*.
- Conjugation**, the union of two gametes (or sexual cells), the resulting organism being called a *zygote*.
- Conjugation-canal**, the bridge which is formed between conjugating cells of *Spirogyra*, &c., and by which impregnation is effected.
- Connate**, united congenitally.
- Conopodium**, a conical receptacle (used of flowers).
- Contorted aestivation**, used when the corolla appears spirally twisted, the petals being so arranged that one margin is external to a neighbouring petal whilst the other is internal to the petal on the other side.
- Contractile cells**, in the anther, form a layer in its wall; their membranes are peculiarly thickened, and by their hygroscopic contractions the anther opens.
- Convolute**, applied to a leaf which is rolled up longitudinally in the bud.
- Cordate**, heart-shaped, as a leaf.
- Corm**, a bulb-like fleshy stem or base of a stem; as "solid bulb", as in *Crocus*, *Colchicum*, &c.
- Cormus**. See foot-note, vol. i. p. 665.
- Corolla**, the inner whorl of the perianth, composed of petals.
- Corona**, in *Narcissus*, &c., a series of ligular structures on petals, which may be either free or united together. It gives the appearance of an additional floral whorl.
- Corpuscle**, a little mass of protoplasm which though imbedded in the general protoplasm of the cell is nevertheless an independent body, e.g. chlorophyll-corpuscle.
- Corpusculum** (of *Asclepiad* pollinium), the little body connecting the pollen-masses and by means of which they become attached to insects.
- Cortex**, the portion of a stem or root external to the vascular tissues.
- Corymbus**, or *Corymb*, a flat-topped inflorescence belonging to the centripetal or indefinite series.
- Cosmic dust**, the minutely divided inorganic particles suspended in the higher strata of the atmosphere; not necessarily of extra-terrestrial origin.
- Cosmopolitan plants** are such as range almost over the entire globe; in contrast to plants that flourish only in a certain locality (*endemic* plants).
- Cotyledons**, seed-leaves; the first leaf or leaves of an embryo.
- Craspedromous**, used of the lateral veins of a leaf which run undivided from midrib to margin.
- Crateriform**, goblet- or cup-shaped.
- Crenate**, said of a toothed leaf-margin, the teeth being rounded; scalloped.
- Cross-fertilization**, the fertilization of an egg-cell by a male cell borne on another individual; fertilization of the ovules of one flower by the pollen from another individual. Occasionally used in error in the text for cross-pollination (which see). Many authors use the term as synonymous with cross-pollination, but the practice is not good.
- Cross-pollination**, the deposition on a stigma of pollen which has been brought from another flower. Cross-pollination, though probably leading to cross-fertilization, is not synonymous with this term.
- Cruciferous**, "cross-bearing", having cross-shaped flowers; used of the characteristically flowered family *Cruciferae*.
- Cryptogamia**, includes all plants exclusive of Flowering Plants: opposed to *Phanerogamia*. An old term, persisting from times when the reproductive processes of these plants were less well-known than to-day.
- Crystalloid**, a crystal-like mass of proteid; a common form under which proteids are stored.
- Culmus**, or *Culm*, the jointed and usually hollow stem of *Grasses* and similar plants.
- Cupule**, the bract-like cup which incloses the nut or nuts in many *Amentiferae*; it is the husk of the hazel-nut, the cup of the acorn, the prickly envelope of the Spanish chestnut, &c.
- Cut**, a term applied to the lobing of leaf-blades; incised; cleft.
- Cuticle**, a continuous film on the surface of a plant, formed of the cutinized outer surfaces of the epidermal cells.
- Cyma**, or *Cyme*, a definite or centrifugal inflorescence: the laterals grow more strongly than the primary axis and overtop it.
- Cyma composita**, or compound cyme; a definite or centrifugal inflorescence, in which the ultimate parts (cymes) are also arranged in a cymose manner.
- Cystolith**, a concretion of carbonate of lime, generally deposited on a little tongue or peg of cellulose projecting into the cells of certain plants.
- Cytoplasm**, the protoplasmic body of a cell as opposed to the nucleus.
- Daughter-cells**, cells which arise by the division of any cell.
- Deciduous**, non-permanent: used of parts of a flower (petals, &c.) which fall after flowering, and of leaves which fall in autumn, &c.
- Decurrent**, used of leaf-blades which have their bases extending downward along the stem.
- Decussate**, applied to leaves which are arranged in pairs alternately crossing each other at regular angles.
- Definitive nucleus**, the nucleus which is formed in the embryo-sac by the fusion of two, one from each end; the endosperm originates from it after fertilization has taken place.
- Dehiscence**, the act or mode of opening of a fruit, anther, spore-capsule, &c. &c.
- Dendritic**, tree-like; repeatedly branched.
- Denizen**, an inhabitant, a plant belonging to a certain district. Strictly (but not so used in K. and

- O.), a plant resembling a native, but suspected of having been originally introduced.
- Dentate**, of leaf margins; toothed—the teeth pointing *outwards*, not forwards or backwards.
- Dermatogen**, the embryonic cellular layer at the apex of a stem or root from which the epidermis is developed.
- Desmid**, one of the Conjugatæ. See vol. ii. p. 655.
- Dextrorse**, used of twining plants which turn from west through south to east, &c.
- Diadromous**, having a fan-like arrangement of leaf-veins, as in Gingko.
- Dialypetalæ**, plants with petals separate from one another (= Polypetalæ).
- Diandria**, the 2nd class of Linnean system; includes all genera with perfect flowers having two stamens.
- Diastase**, a solid, white, soluble substance found in Oats, Potatoes, &c., after germination.
- Diastole**, used of the rhythmic expansion of a contractile cell or vacuole.
- Diatom**, a single organism inclosed in a bivalved siliceous test or frustule. See vol. ii. p. 625.
- Diatomin**, the brown pigment of Diatoms.
- Dichogamy**, the maturing of pollen and stigma in a hermaphrodite flower at different times, to prevent self-fertilization.
- Dicotyledon**, plant with two seed-leaves or cotyledons.
- Dictyodromous**, or reticulate venation, are terms applied to lateral veins of leaves which break up into a network before reaching the margin.
- Didynamia**, the 14th class of the Linnean system, which includes flowers with four stamens, two long and two short.
- Didynamous**, applied to flowers having four stamens, one pair longer than the other.
- Diœcious**, unisexual; the male and female flowers being on separate plants.
- Diosmosis**, the transfusion of a fluid through imperceptible openings in a membrane.
- Diptero-ccidia**, gall-structures, due to dipterous insects.
- Discoid**, resembling a disc.
- Discomycete**, any Fungus belonging to the group Discomycetes, i.e. an Ascomycete in which the fruiting body is disc-shaped.
- Discomycetous**, pertaining to the group of Fungi Discomycetes.
- Discopodium**, a disc-shaped floral receptacle.
- Disintegration**, a resolution of a tissue into its constituent cells, or of any body into its constituents.
- Displacement**, in whorls, applied to the shifting of places of insertion of members, so that successive whorls are placed immediately above one another.
- Divergence**, applied to the angle between the insertions of successive leaves on a stem.
- Divided**, used of leaf-blades to express the fact that they are deeply lobed.
- Dormant eyes or buds, or Reserve-buds**; are buds which arise in the leaf-axils in the usual way, but which do not forthwith expand into shoots; they remain—often many years—until stimulated into activity by some special event.
- Drupaceous**, of the nature of a drupe.
- Drupe**, a succulent fruit with hard, stony endocarp, which incloses a single seed. Many-seeded drupes are rare.
- Duct**, a continuous tube, arising either by the running together of cells (fusion), or by the separation of cells, when it is lacunar in nature; a canal formed by a row of cells having lost their partitions.
- Dwarf-male**, of *Oedogonium*; the little few-celled plant arising from an androspore which gives rise to the spermatozooids. It is formed adjacent to the oogonium.
- Ectoplasm**, the pellicle-like outmost layer of protoplasm in a cell. It is clear and hyaline, and less fluid than the endoplasm.
- Egg-cell, or Ovum**; the female generative cell.
- Elaters**, (1) in Liverworts, filamentous cells, with spiral thickenings, which are present with the spores, and, owing to their hygroscopicity, assist in their dispersal; (2) in *Equisetum*, arm-like appendages of the spores, by the contractility of which the spores become entangled in groups.
- Ellipsoidal**, having the form of an elliptical solid.
- Embryo**, the rudimentary plant; in seeds, that stage of the young plantlet at which the resting-stage supervenes.
- Embryo-cell**, the cell borne at the distal end of the suspensor, which gives rise to the embryo, or to the greater part of it.
- Embryo-sac**, the large cell in the nucellus of an ovule, in which the egg-cell, and ultimately the embryo, arises.
- Endemic**, restricted to a given region or locality.
- Endophytic**, living within the tissues of another plant, though not necessarily parasitic upon them.
- Endoplasm**, the soft, inner granular protoplasm of a cell.
- Endosmosis**, the transmission of fluids through porous membranes from the exterior to the interior.
- Endosperm**, the tissue produced within the embryo-sac of flowering plants, and which in many cases becomes stored with food-materials for the embryo.
- Endospores**, asexual reproductive cells produced inside the original cells in Bacteria.
- Endothecium**, in flowering plants, the layers of the wall of the anther internal to the exothecium.
- Ennobling**, the art of transferring a branch or bud of one plant to another, and causing them to unite.
- Entire**, untoothed: applied to the leaf-margin, petals, &c.
- Entomophilous plants**, such as have flowers pollinated by insect agency.
- Enzyme**, any of the unorganized ferments which exist in seeds, as diastase, pepsin, &c.
- Ephemeral**, applied to flowers which endure only for a few hours or for a day; opening but once.
- Epicotyl**, the portion of a plant above the cotyledons; restricted to embryos and seedlings.
- Epidermis**, that layer of cells which forms the enveloping mantle of multicellular plant-bodies. It may be replaced in perennial plants by cork.
- Epigeal**, growing above the ground.
- Epiphragm**, of Mosses: the membrane remaining after the fall of the operculum, stretched across the mouth of the capsule in Polytrichaceæ.
- Epiphyllous**, applied to structures growing on leaves.
- Epiphytes**, plants growing attached to other plants (or animals), but not parasitically.
- Equitant**, riding; folded around, as if straddling over.
- Erythrophyll**, a red sap-pigment frequent in foliage-leaves, especially in autumn.

Ethereal oils, oils of wide occurrence in plants, and of various chemical composition; to the presence of these ethereal or volatile oils are due most of the odours of plants.

Evolute, turned back.

Exalbuminous, applied to seeds which are destitute of endosperm or perisperm, the food-material being stored in the embryo itself.

Excoriation, of glandular hairs; applied to the act of throwing off the cuticle as a blister.

Exfoliate, to come away in scales or flakes, as the bark of a tree.

Exine. See *Eatine*.

Exogamy, the tendency often exhibited by closely related gametes to avoid pairing.

Exosmosis, the passage from within outwards of fluids through a membrane.

Exothecium, the outmost layer or epidermis of an anther.

Exstipulate, without stipules: often used (though erroneously) in cases where the stipules are early deciduous.

Eutine, the outer coat or membrane-layer of a pollen-grain. It is, however, internal to the perine.

Extravasation, an escape from the proper vessels into surrounding tissues: used of fluids.

Extorse, applied to such anthers as open towards the outer whorls of a flower, i.e. away from the gynoecium.

Eye, of Potato, &c.; an undeveloped bud.

Eye-spot, in motile gametes and spermatozooids, a little red pigment-body contained usually in the anterior extremity, and supposed to be sensitive to light. Cf. vol. ii. p. 629.

Fairy-ring, a phenomenon observed in meadows, and due to the growth of certain Fungi. Cf. vol. ii. p. 792.

Fasciation, used of monstrous expansions of stems, which resemble several stems fused together in one plane.

Fascicula, or **Fascicle**, a dense cluster of flowers, leaves, roots, &c.

Father-plant, the stock from which the pollen is derived: used in connection with hybrids.

Ferment, a substance produced by the protoplasm, which induces chemical change or fermentation in some substance without itself entering into or being affected by the process.

Fertilization, the process by which the pollen reaches and acts upon the ovules, and results in the production of fruit; impregnation.

Fertilizing-tube, in *Peronospora*, the tubular outgrowth of the antheridium which penetrates the oogonial wall and by which the male substance passes to the egg-cell.

Fibre, any delicate filament; also, a thick-walled tapering cell.

Fibrils of nucleus; the segments into which the nuclear reticulum breaks up at division; they are also termed *chromosomes*.

Fibrous layer, of anther: the specially thickened portion of the wall which brings about dehiscence.

Filament, the stalk of an anther.

Filiform, slender, thread-like.

Fimbriate, fringed by fine subdivision of the margin; having fine, hair-like marginal processes.

Fistular, hollow, reed-like.

Flagellum, the whip-like process or filament of protoplasm which serves as an organ of motility; also a shoot sent out from the bottom of a stem, as in the strawberry; a runner.

Floccose, composed of or bearing soft hairs or wool.

Flora, the aggregate of the plant-population of any district; also, the term given to a systematic description of the same.

Floral, belonging to the flower.

Floret, a small flower in a cluster or in a compact inflorescence, as in the *Compositæ*.

Flower, in *Phanerogams* the growth which comprises the reproductive organs and their envelopes; a shoot modified for the production of spores (pollen-grains and embryo-sacs).

Flowering glume, the outer of the two chaffy scales inclosing the several flowers of a grass; it is frequently awned.

Folium fulcrans, the subtending leaf of a flower; a bract.

Follicle, a monocarpellary dehiscent fruit opening only down the ventral suture.

Foot, the sucker by means of which a young Fern-plant is temporarily attached to the prothallium.

Foreign, applied to pollen from another flower.

Frugivora, animals which live upon fruits.

Fruit, defined vol. ii. p. 47.

Frustule, the siliceous valve of a *Diatom*.

Frutex, a shrub.

Fruticose, pertaining to shrubs; shrubby.

Fruticulus, a little shrub.

Fuliginous, having the colour of soot.

Fundamentum, the hypocotyl, which see.

Fungus, a cellular *Cryptogam*, distinguished for its want of chlorophyll; it is either saprophytic or parasitic.

Funicle, the stalk of an ovule or seed; a funiculus.

Furfuraceous, scurfy; covered with bran-like scales.

Fusiform, spindle-shaped: applied to roots, &c., which taper both ways from the middle, as the radish.

Galeate, helmet-shaped; having a galea or helmet.

Gall, a vegetable excrescence produced by the deposit of the egg of an insect in the bark or leaves of a plant; a hypertrophied growth due to some irritating cause.

Gametangia, cells from which gametes are developed.

Gamete, a sexual cell.

Geitonogamy, crossing between separate flowers growing on the same plant.

Gemma, a small undeveloped shoot; a shoot-bud.

Gemination, the act or process of budding.

Generative cell, in pollen-grains, that cell which ultimately fertilizes the egg-cell.

Genetic spiral, the spiral line passing through the point of insertion of equivalent lateral members (leaves) on an axis in order of age from older to younger.

Genus, an assemblage of species; its name, together with that of the species, gives the name to the plant.

Geotropism, applied to the power or tendency of some plants to grow towards the earth.

Germen, the ovary.

Germination, the act, process, or result of evolving the embryo of a seed into a young plant.

- Gills**, the radiating plates on which the basidiospores of Agarics are produced.
- Glabrous**, without hairs; quite smooth.
- Glandular**, having the nature of a gland, bearing glands.
- Gleba**, the chambered, sporogenous layer of a Gasteromycetous Fungus.
- Globoid**, the tiny mass of magnesium and calcium phosphate which is often present in aleurone grains (which see).
- Glomerule**, a cymose inflorescence formed into a head, as in the Globe-thistle.
- Glucoside**, a compound consisting of glucose and an aromatic body.
- Glumes**, the chaffy, bract-like scales on the inflorescences of Grasses and Sedges.
- Goneoclinic**, used of hybrids which approximate to one or other parent-form rather than standing midway between them.
- Graft-hybrid**, a hybrid supposed to have arisen by budding or grafting.
- Gynandria**, the 20th class of the Linnean system. Cf. vol. ii. p. 290.
- Gynœceum**, the carpel, or aggregate of carpels, in a flower; the female portion of a flower as a whole.
- Habitat**, the natural abode of a plant.
- Hæmatochrome**, the red pigment found in the eyespots of Chlamydomonadæ and zoospores.
- Halophytes**, plants which flourish on soils rich in salt; saltworks.
- Haulm**, the stalk of a grass of any kind.
- Haustorium**, the sucker of a parasitic plant.
- Herbaceous**, of the colour, texture, &c., of a herb.
- Herbal**, a book of descriptions of plants with especial reference to their medicinal properties; herbals were usually copiously illustrated.
- Herbarium**, a collection of dried plants systematically arranged. (Formerly it signified an illustrated herbal.)
- Hermaphrodite**, applied to a flower which has both stamens and carpels.
- Heterochromatism**. *Vide* vol. ii. p. 569.
- Heterœcism**, the act of passing through different stages of development on different hosts; as in Fungi.
- Heterogamous**, applied to plants that bear two kinds of flowers which differ sexually.
- Heterogamy**, the state or quality of being heterogamous (which see); cross-pollination.
- Heteromorphism**, here used to designate the various modifications of equivalent members in connection with different functions, analogous to that existing among the polyps of a coral.
- Heterophyllous**, bearing leaves of more than one form on the same stem; applied especially in respect of foliage-leaves.
- Heterosporous**, having spores of different kinds, especially macrospores and microspores.
- Heterostyled**, when the flowers of a plant differ in the relative length of their styles: opposed to *homostyled*.
- Hilum**, (1) of starch-grain; the centre around which the stratifications are deposited; (2) of a seed; the scar or place of attachment.
- Hirsute**, bearing rather stiff hairs.
- Holosericeus**, covered with fine silky hairs.
- Homochromatism**. *Vide* vol. ii. p. 569.
- Homosporous**, having spores all of a kind.
- Homostyled**. *See Heterostyled*.
- Hortus vivus**, an old term for a dried collection of plants, now called a *herbarium* (*hortus siccus* is also used in the same sense).
- Humus**, vegetable mould; a soil largely composed of decaying vegetable matter.
- Hybrid**, a plant resulting from the intercrossing of more than one species.
- Hybridization**, the act of crossing different species and so producing hybrids.
- Hydrophytes**, plants which live in water.
- Hydrotropism**, the particular irritability of plant-members (especially roots) whereby they respond by curvatures to moisture in the environment, turning towards or away from it.
- Hymenium**, hymenial layer; the spore-bearing surface of a fungal receptacle.
- Hypanthium**, a term given to any special enlargement of the receptacle, as in the Rose.
- Hypha**, the filamentous element of the thallus of a Fungus.
- Hyphodromous**, used when the veins of a leaf run so that they are not visible on the surface.
- Hypocotyl**, the portion of the stem below the cotyledons.
- Hypocrateriform**, salver-shaped: used of corollas, &c., which are tubular below and suddenly expand into a flat limb.
- Hypogeal**, underground; growing beneath the surface of the earth.
- Hysterophyta**, Endlicher's term for the parasitic flowering plants.
- Idioplasm**, name applied by Nægeli to that portion of the protoplasm in which the formative activity was supposed to reside—the active, organizing portions of the protoplasm.
- Illegitimate union in heterostyled flowers**. *Vide* vol. ii. p. 405.
- Imbricate æstivation**. *Vide* vol. ii. p. 210.
- Imbricating**, overlapping like the tiles of a roof.
- Incised**, of leaves, cut irregularly and sharply.
- Indumentum**, a hairy covering or coating.
- Indusium**, the scale-like outgrowth of a Fern leaf enveloping the sorus.
- Inferior**, (1) of the ovary; adherent to the calyx (cf. also vol. ii. p. 79); (2) of the calyx, free from the ovary; (3) in regard to the relation of parts of flower to the axis; farthest from the axis.
- Inflorescence**, the mode of branching of the flower-bearing part of a plant; or, the actual cluster of flowers (the common use of the term).
- Infundibuliform**, Infundibular, funnel-shaped.
- Innovatio**, a new-formed shoot.
- Insectivorous plants**, plants which catch insects and absorb their juices.
- Integument**, the envelope—single or double—of an ovule.
- Internode**, the portion of a stem between the points of insertion of leaves.
- Intine**, the internal layer of the wall of a pollen-grain.
- Introrse**, of the anther; dehiscing towards the centre of the flower.
- Intussusception**, the taking up by a living organism of new particles between those already in existence.

Invertin, a ferment which converts cane-sugar into glucose.
Involucral, appertaining to the involucre.
Involucre, a circle of bracts inclosing a capitulum or other crowded inflorescence.
Involute, rolled inward.
Isogametes, equivalent gametes or sexual cells.
Isoplanogametes, in Algae; motile sexual cells which are equal in size.

Kamptodromous. See vol. i. p. 630.

Labellum, the median member of the inner perianth-whorl in Orchids.

Laciniated, cut into narrow lobes.

Lacuna, a space, especially an intercellular space, originating by the separation or breaking down of cells.

Lamella, a thin plate as in the gills of Agarics. See *Gills*.

Lanceolate, shaped like a lance-head; narrower than oblong, and tapering towards the apex.

Latex, plant juice, often a milky juice.

Laticiferous, containing latex.

Leaf-axil, the angle formed by a leaf and the portion of stem immediately above its point of insertion.

Leaves, laterally-developed members of limited growth, which spring in geometrical succession from the outer layers of tissue below the growing point of the stem.

Legitimate union, in heterostyled flowers. *Vide* vol. ii. p. 405.

Legume, or **Pod**; a monocarpellary fruit dehiscing down both sutures.

Lepidote, -us, beset with scurfy scales.

Liane, **Liana**, a climbing plant with a woody, perennial stem.

Libriform cells, strong, spindle-shaped cells with inconspicuous pittings, thick walls, and usually destitute of protoplasmic contents. They occur in wood.

Lichen, an organism compounded of a Fungus and an Alga living together symbiotically.

Lignin, an aromatic substance (or number of substances) present in the membrane of woody tissue. To it are due the characteristic properties of wood.

Ligulate, provided with a ligule.

Ligule, **Ligula**, (1) the thin scarious projection from the summit of the leaf-sheath in Grasses; (2) the corolla of a ray-floret in the Compositae; (3) a tongue-like outgrowth on the leaf met with in *Selaginella* and *Isoetes* just above the insertion of the sporangium.

Linear, several times narrower than long, with the margins parallel.

Linear-lanceolate, intermediate in form between linear and lanceolate.

Lines of vegetation, for any species, are the lines obtained by joining all the places in a given direction at which that species is checked in its distribution by climatic or other conditions; the resultant figure obtained by joining all the lines of vegetation covers the distribution of the species in question, and may be termed the line of distribution.

Lithophytes, plants which grow on stones, and derive their nutriment in the main from the atmosphere.

Liverwort, a term applied to any member of the Hepaticae.

Lobe, any division of an organ; a rounded projection or division.

Lodicules, tiny scales, usually two in number, which occur in the flowers of Grasses, and are supposed to represent the perianth.

Lomentum, a legume which separates into 1-seeded articulations or joints.

Macropodous, applied to embryos in which the hypocotyl is enormously enlarged, constituting the greater part of the embryo.

Macrospores, used of the larger (so-called female) spores of heterosporous plants: opposed to *microspores*.

Manubrium, the cell in the antheridium of Characeae which projects inwards from the shield, and ultimately bears the antheridial filaments.

Medulla, pith.

Megagametes, used of the larger, and presumably female, motile sexual cells of certain Algae.

Melliferous, honey-bearing.

Mericaip, one of the achene-like fragments into which a syncarpous, polycarpellary fruit (schizocarp) breaks up. Used especially of Umbelliferae.

Meristem, embryonic tissue: growing cell tissue at the ends of young stems, roots, &c.

Mesophyll; the whole of the internal ground-tissue of a leaf-blade.

Metabolism, the chemical changes which take place in the protoplasm and which it causes in other substances; the phenomena resulting from chemical changes in the protoplasm.

Micellæ, name given to molecular aggregates, just as molecule is the name given to atomic aggregates.

Microgametes, used of the smaller, presumably male, motile sexual cells of certain Algae.

Micro-millimeter (μ), the one-thousandth part of a millimeter.

Micropyle, the aperture left in the integument of an ovule by means of which the pollen-tube gains access (except in chalazogamic plants) to the embryo-sac.

Microsomata, tiny granules of various nature embedded in the protoplasm. Not a good term.

Microspores, the smaller or so-called male spores of heterosporous plants: opposed to *macrospores*.

Midrib, the central or main vascular bundle of a leaf.

Monadelphous, when the stamens are all united together by their filaments into a tube or column.

Monandria, the 1st class of the Linnean system. See vol. ii. p. 288.

Moniliform, like a necklace or string of beads.

Monocarpellary, consisting of one carpel.

Monocotyledonous, having only a single cotyledon or seed-leaf.

Monœcia, the 21st class of the Linnean system. See vol. ii. p. 290.

Monœcious, having male and female flowers on the same individual.

Monotypic, term used of genera which comprehend but a single species, *e.g.* *Welwitschia*.

Morphology, that department of botanical study which deals with the form of the plant-body, including its development, the growth of its distinct members, &c.

Mother-plant, that parent of a hybrid upon which the seed is matured.

Mycelium, the filamentous vegetative body of a Fungus.

Myco-ecidium, a gall which owes its origin to the attacks of Fungi.

Mycorrhiza, a root invested by a fungal mantle: supposed to be a case of symbiosis.

Mycosis, a diseased condition of animal tissues alleged to be due to the presence of a Mould-fungus.

Myrmecophilous, used of plants which attract ants, the latter often living altogether upon the plant and affording it protection against certain enemies.

Nectary, a honey-secreting gland or part of a flower.

Neroli, Oil of, the ethereal oil yielded by the flowers of the Orange-tree.

Neuter flowers, flowers destitute of functional stamens or carpels.

Node, the part of a stem at which a leaf or whorl of leaves is inserted.

Nodose, or **Nodosus**, knotty; having well-marked nodes or knots.

Nodulated, having small knots: diminutive of *nodose*.

Nucellus, the central portion or body of an ovule, containing the embryo-sac.

Nuclear plate, the assemblage of nuclear fibrils in the equator of a nucleus during the division of the latter.

Nucleus, (1) of starch-grain, same as hilum; (2) of an ovule, an old term for *nucellus*; (3) the cell-nucleus, a specialized portion of the protoplasm of a cell exhibiting remarkable figures during division and presiding over the chemical processes that take place in the cell.

Nut, a hard, indehiscent, 1-seeded fruit resulting from a polycarpellary ovary.

Nutation, spontaneous changes in position of growing organs; a kind of oscillation or regular movement in parts of plants.

Obovate, ovate with the broader end at the apex.

Omphalodium, the scar at the hilum of a seed.

Ontogeny, the history of the individual development of an organized being.

Oogonium, the cell in which the female sexual cell or cells are produced; especially amongst Thallophytes.

Oophyte, that stage in the life-cycle of a plant which bears the sexual organs.

Ooplasm, the substance of which the female sexual cell consists. Not a good term.

Ooplast, the female sexual cell. Not a very good term.

Oospore, a fertilized egg-cell.

Operculum, the lid of a Moss capsule.

Order, a division of plants intermediate between class and genus, consisting usually of a group of genera related to one another by structural characters common to all. Same as *family* as used in this book.

Orthostichies, vertical ranks of leaves. Cf. vol. i. p. 397.

Orthotropous, applied to an ovule with straight nucellus wherein the micropyle is at a point far removed from the funicle.

Osmosis, the tendency of fluids to pass through

porous membranes; the phenomena attending the passage of fluids through porous membranes.

Ostiole, the aperture of the conceptacle in the Fucaceae.

Ovary, the part of the pistil that contains the ovules or immature seeds; the closed chamber-like portion of a single free carpel, or the many chambers of several united carpels in which the ovules are produced.

Ovule, in Phanerogams is the macrosporangium or nucellus with its integuments, and containing the embryo-sac. The ovule is the immature seed.

Ovuliferous scale, the ovule-bearing scale of Conifera.

Palæo-botany, Fossil botany.

Palate, a projection in the throat of a personate corolla (or corolla such as that of the Snapdragon).

Palea, the inmost of the glumes which inclose the individual flowers of Grasses; a chaffy scale or chaff-like bract.

Palisade-cells, the green assimilating tissue, consisting of cylindrical cells, usually found towards the upper surface of the leaf-blade.

Palmate (of leaf-blades), lobed so that the projections radiate from the point of insertion.

Panicle, a loose branched cluster of flowers. Not applied very strictly.

Papilionaceous, like a butterfly: a term applied to the corolla of a section of Leguminosae, including the Pea and Bean, &c.

Papilla, a minute nipple-shaped projection.

Papillose, bearing papillae.

Pappus, the hairy or feathery development of the calyx of a Composite plant, which promotes dispersal by wind; thistle-down or the like.

Parallelodromous. See vol. i. p. 634.

Paraphyses, sterile filaments accompanying the sexual organs in Moesses, the asci and basidia of Basidiomycetes, and in other cases.

Parasite, a plant which lives upon and obtains organic nutriment from the tissues of a living plant (or animal).

Parastichies, secondary spirals in the arrangement of leaves.

Parenchyma, usually thin-walled tissue consisting of cubical or polygonal cells, and forming the pulp of leaves, fruits, &c.

Parthenogenesis, the development of an egg-cell into an embryo without fertilization taking place.

Parthenogonidia, certain reproductive cells in a Volvox-colony which propagate the plant asexually.

Partite, cleft, but not quite to the base.

Patelliform, disc-shaped; circular with a rim.

Pedate venation. See vol. i. p. 633.

Pedicel, an ultimate flower-stalk bearing a single flower.

Pedunculus, or **Peduncle**, a general flower-stalk bearing either a single flower or a closely-crowded cluster of flowers.

Peltate, shield-like: said of leaves when the petiole is attached to the under surface of the blade and not to the margin.

Perfoliate, appearing as if perforated by a stem: said where a stem is so embraced by a leaf that the former seems to pass through the latter.

Perianth, the floral envelope, consisting of calyx or corolla, or both: used especially when it is not easy to distinguish between them.

- Periblem**, the embryonic tissue at a growing point from which the primary cortex arises.
- Pericarp**, -ium, the wall of an ovary that is developed into a fruit.
- Perichæcium**, the sheathing structures in Muscineæ which envelop the clusters of archegonia and antheridia.
- Peridium**, the outer envelope investing the fructification in certain Fungi.
- Perine**, the outmost layer of sculpturing on the membrane of pollen-grains.
- Perisperm**, the tissue of the nucellus, in which, sometimes, food material is stored for the ultimate use of the embryo. It is external to the embryo-sac. In many old systematic books it is used for all food-material of seeds which is external to the embryo.
- Peristome**, the ring of teeth around the mouth of a Moss capsule.
- Perithecium**, the flask-shaped cavity in which asci are produced in certain Fungi.
- Petal**, a corolla-leaf.
- Petaloid**, -ine, like a petal.
- Petiole**, the stalk of a leaf.
- "**Petit grain**", name for the ethereal oil yielded by the leaves of the Orange-tree.
- Phænology**, that branch of botanical investigation which deals with the recording, tabulation, and comparison of the times and seasons at which plants open their flowers and perform other periodic functions in various portions of the globe.
- Phanerogamia**, seed-bearing or flowering plants.
- Phloem**, soft bast; the soft outer portion of a vascular bundle, of which sieve-tubes are the most characteristic constituents.
- Phrygana**, an old term for a growth of stiff and prickly under-shrubs.
- Phycocyanin**, the blue pigment of the Cyanophycææ or lowest Algae.
- Phycophæin**, the brown pigment of the Brown Algae.
- Phycocerythrin**, the purple colouring-matter of Red Sea-weeds.
- Phylloclade**, a branch assuming form and function of a foliage-leaf: same as *cladode*.
- Phyllode**, a petiole assuming the form and function of a leaf-blade.
- Phyllotaxis**, leaf-arrangement; the arrangement or order of distribution of leaves on the stem.
- Phylogeny**, or **Phylogenesis**, the history of the genealogical development of an organized being; the race history of an animal or plant, as distinguished from *ontogeny*, the history of individual development.
- Phylum**, a main division of the vegetable kingdom.
- Pileus**, the cap-shaped receptacle of a Basidiomycetous Fungus; the umbrella-like part of a mushroom.
- Pili fasciculati**, tufted hairs.
- Pili stellati**, stellate hairs.
- Pinnate**, when leaflets are arranged on either side of a common rachis or petiole.
- Pistil**, the female organ of a flower, consisting of ovary (style) and stigma; if the carpels are apocarpous there are many pistils; if syncarpous, only one.
- Pistillate**, said of a plant or flower containing a pistil; most correctly, of one having no stamens.
- Pitcher**, a tubular or excavated leaf, usually containing a liquid; an ascidium.
- Pith**, the central cellular part of a stem or root.
- Pits**, thin places or depressions on cell-walls.
- Placenta**, the part of the carpel which bears the ovules; in Vascular Cryptogams, the portion of leaf-surface bearing the sporangia.
- Plaited**, folded; folded into plaits lengthwise; plicate.
- Plant-formation**, a term used to indicate the presence of two or more types of plant-community intermingled together, often in obvious strata. Cf. vol. ii. p. 896.
- Plasmodium**, in the Myxomycetes; a mass of naked multi-nucleate protoplasm exhibiting amoeboid movements.
- Pleomorphism**, the occurrence of more than one independent form in the life-cycle of a species, especially in Fungi and Bacteria.
- Pleurocarpous**, used of Mosses in which the archegonia are borne, not at the tips of the main but of secondary shoots.
- Plicate**, of aestivation; folded lengthwise in plaits.
- Plumule**, the rudimentary shoot of an embryo.
- Pod**. See *Legume*.
- Podium**, a term for the torus or floral receptacle.
- Polar nuclei**, the two nuclei—one from each end of the embryo-sac of Angiosperms—which approach one another and fuse to form the definitive nucleus of the embryo-sac.
- Pollarding**, the act of removing the crown of a tree so as to induce it to throw out branches around the place of amputation.
- Pollen**, the mass of fecundating cells or grains contained in the anther.
- Pollen-grain**, one of the fecundating cells of the pollen; the microspore in flowering plants.
- Pollen-sac**, the sporangium in which the microspores or pollen-grains of flowering plants are developed.
- Pollen-tube**, the tubular outgrowth of a pollen-grain by means of which fertilization is achieved.
- Pollinia**, masses of coherent pollen-grains.
- Polycarpellary**, having or consisting of a number of carpels.
- Polychotomous**, branching repeatedly into equivalent portions.
- Polyembryony**, the production of more than a single embryo in an ovule.
- Polyhedra**, angular bodies which arise from the zoospores into which the zygote of Hydrodictyon breaks up. Ordinary Hydrodictyon-nets arise inside them.
- Porogamic**, used of flowering plants in which the pollen-tube effects an entrance to the ovule by the micropyle.
- Porous**, used of dehiscence of anthers, &c., by means of holes.
- Prickle**, a sharp-pointed process of the epidermis or cortex, but destitute of vascular tissue.
- Primordial utricle**, that portion of the cell-protoplasm which forms a bag in contact with the cell-wall. An old name which has persisted in the terminology.
- Procumbent**, lying along the ground.
- Prolepsis**, something of the nature of an anticipation. See vol. i. p. 8.
- Pro-mycelium**, the limited tubular growth arising from the chlamydozoospores in Hemibasidii and Uredineæ, from which conidia are abstricted.
- Prostrate**, lying flat on the ground.

- Protandrous, Proterandrous**, used of flowers when the anthers dehisce before the stigmas are receptive.
- Proteid**, a nitrogenous substance of complex constitution, generally of a viscid nature and rarely crystallizable. The proteids include albumin, globulin, peptone, &c.
- Prothallus, -ium**, the structure produced by the germination of the spore of Ferns, bearing sexual organs, and from which the young plant arises and derives nourishment for a time; also the homologue of this in flowering plants.
- Protogynous, Proterogynous**, used of flowers in which the stigmas are receptive before the pollen of the same flower is discharged.
- Protonema**, the filamentous growth of a Moss from which the leafy shoots arise by budding.
- Protoplasm**, the living and formative organic substance of plants and animals; living matter in its simplest form, serving as the basis of both animals and plants, and consisting of carbon, oxygen, hydrogen, and nitrogen, colourless, transparent or nearly so, and somewhat viscid in consistence.
- Protoplast**, the protoplasmic cell-body; a simple one-celled organism.
- Pseudo-hermaphrodite** flowers are such as have been functionally unisexual by the suppressing of either stamens or carpels.
- Pseudomorph**, a term borrowed from mineralogy; an unusual or altered form. Cf. vol. i. p. 185.
- Pulverulent**, powdery.
- Pulvinate**, cushion-like.
- Pulvinus**, the enlargement of a petiole or leaf-stalk at its point of insertion on the stem, or of a secondary petiole at its point of insertion on the leaf-rachis.
- Pycnidium**, in Fungi; a receptacle or cavity of varying form, in which conidia (pycno-conidia) are produced: especially in Ascomycetes.
- Pyrenoids**, refractive bodies imbedded in the chlorophyll of many Green Algae.
- Race**, a variety or form not distinguished by characters important enough to rank as a species, but reproduced by seed and transmitting its characters to the offspring; also loosely used for a group of allied individuals without regard to rank.
- Racemus, Raceme**, an indefinite or centripetal inflorescence with pedicellate flowers.
- Rachis**, the axis of a compound leaf, or of a spike or other indefinite inflorescence.
- Radical**, belonging to or arising from a root, or from a root-like portion of the stem below the ground.
- Radices adligantes**, clinging roots.
- Radices columnares**, columnar roots.
- Radices fulcrantes**, stilt-like roots.
- Radices parietiformes**, or tabular roots. See vol. i. p. 754.
- Radices tuberosæ**, or tuberous roots; roots beset with tuber-like enlargements.
- Radicle**, the root of an embryo; usually not separable from the hypocotyl.
- Radix**, the root.
- Raphe**, that part of the stalk of an anatropous ovule which is fused with the body of the ovule; in Diatoms, the median line on the frustule, possibly a slit.
- Receptacle**, of a flower; the abbreviated or flattened axis upon which the various floral members are inserted.
- Reniform**, kidney-shaped.
- Replum**, the framework, or frame-like placenta, which remains in Cruciferous and other fruits after the valves have fallen away.
- Resilient**, springing back, rebounding: used of fruit-stalks, stamens, &c.
- Resin-duct**, an intercellular passage into which resin is secreted and where it is stored.
- Respiration**, the term applied to the absorption by a plant of free oxygen from, and evolution of carbon dioxide into the air. It is the outward sign of a destructive oxidative process going on within the plant, by means of which latent energy is rendered available.
- Revert, Reversion**, a sudden return or breaking back to an ancestral form.
- Revolver-flowers**. See vol. ii. p. 249.
- Rhizoids**, the hair-like filaments of Mosses and Liverworts, which perform the functions of roots.
- Rhizome**, an underground (or prostrate) stem of root-like appearance from which roots and herbaceous stems arise.
- Rhizomorph**, name given to the curious vegetative phase of *Agaricus melleus*, which resembles a root.
- Rhizophore**, a leafless branch of peculiar construction which, in *Selaginella*, arises at the place where ordinary branching takes place, and bears roots at its free end.
- Rhizotomoi**, a guild of herbalists in ancient Greece.
- Ring, Annual**, the zone of wood formed from the cambium in the course of one season in a Conifer or Dicotyledon.
- Ringent**, gaping, as the mouth of a bilabiate corolla.
- Ringing**, the act of removing from a branch or trunk a circular zone of bark right down to the wood.
- Root-cap**, the cellular cushion produced at the apex or tip of a root.
- Root-stock**. Same as *rhizome*.
- Rostellum**, the morphological apex of the gynœceum of an Orchid; usually a beak forming the boundary between the stamen and stigma in Orchids.
- Rosulate**, collected in form of a rosette.
- Rotate**, wheel-shaped; circular and horizontally spreading.
- Runner**, a prostrate filiform branch which is disposed to root at the end or elsewhere.
- Samara**, an indehiscent winged fruit, as the *key* of the Ash or Maple.
- Saprophyte**, a plant which grows on dead and decaying organic matter.
- Scabrous**, rough to the touch.
- Scape**, or **Scapus**, a peduncle rising from the ground.
- Scarious**, thin, dry, and membranaceous, and not green.
- Schizocarp**, a polycarpellary fruit which breaks into 1-seeded portions.
- Sclerotic-cell**, a hard, thick-walled cell, often of irregular form; sclerotic cells may be united together into layers, or isolated in soft parenchyma.
- Sclerotium**, in Fungi a tuber-like mass of hyphæ, which, after remaining dormant for a while, ultimately sprouts, producing fructifications. In the *Myxomycetes* it is the resting-stage of the plasmodium.
- Scorpioid cyme**, a definite inflorescence rolled up towards one side like a crook: common in *Boraginaceæ*.

- Scutellum**, the sucker or cotyledon of a Grass embryo.
- Scutiform**, having the form of a shield.
- Seed**, the fertilized and matured ovule.
- Seed-coat**, the integument of the seed, formed from the investment or investments of the ovule.
- Seedling**, a young plant raised from a seed.
- Semifrutex**, or Semi-shrub, a shrub the shoots of which become woody at the base only, this portion alone being perennial.
- Sepal**, a leaf-member of the calyx.
- Sepaloid**, resembling a sepal.
- Separation-layer**. See *Absciss-layer*.
- Septum**, a partition; a thin wall separating compartments.
- Sericeus**, silky; clothed with soft straight hairs.
- Serrate**, of leaf-margins; beset with teeth pointing towards the apex.
- Sessile**, destitute of stalk, petiole, or pedicel.
- Seta**, a bristle; the stalk of the spore-capsule in a Moss or Liverwort.
- Shoot**, that portion of the plant which is differentiated into stem and leaves and bears the reproductive organs.
- Sieve-cells**, cells which have pores in their walls causing a sieve-like appearance; sieve-tubes.
- Sieve-plates**, areas in the walls of sieve-cells or sieve-tubes perforated by pores.
- Sieve-tube**, an articulated tube whose contiguous elements communicate by means of open pores aggregated together upon sieve-plates. The sieve-tube is the characteristic element of the phloem.
- Siliqua**, the fruit of a Cruciferous plant, a longish pod or seed-vessel. Cf. vol. ii. p. 432.
- Sinistrorse**, used of twining stems which turn from north through west to south, &c.: the opposite of *dextrorse*.
- Sinuous**, **Sinuate**, used of a leaf-margin which is strongly indented in a wavy manner.
- Sling-fruit**, a general term given to any fruit which, in virtue of the possession of contractile tissues, throws its seeds to a distance, or is itself so thrown.
- Soboles**, a thin creeping stem, often subterranean.
- Soredium**, the 'brood-body' or 'brood-bud' of a Lichen, consisting of a few algal cells wrapt round with a web of fungal hyphæ.
- Sorus**, a cluster of sporangia, such as those of Ferns.
- Spadiciform**, like a spadix.
- Spadix**, a fleshy spike.
- Spathe**, a large bract-like sheath inclosing an inflorescence.
- Spatulate**, like a spatula, oblong with the lower end attenuated.
- Species**. Under this term may be included all individuals which possess in common such a number of characters that they may be regarded as being descended from a common ancestral form.
- Spermatorium**, a male sexual cell which becomes free, but is unprovided with special organs of locomotion.
- Spermatoplasm**, the protoplasm of the male sexual cell.
- Spermatoplast**, a male sexual cell.
- Spermatozoid**, a free-swimming male sexual cell provided with cilia as organs of locomotion.
- Spike**, an indefinite inflorescence with flowers sessile on an elongated axis.
- Spine**, a sharp-pointed body possessing vascular tissue, commonly a branch or some portion of a leaf.
- Sporangiole**, in the Fungi; a small sporangium, usually containing few spores, and larger many-spored sporangia being also present.
- Sporangiophore**, that which bears sporangia; a scale bearing sporangia in Equisetum.
- Sporangium**, a sac within which spores are developed.
- Spore**, a reproductive cell which becomes free, and is capable of developing into a new individual.
- Sporidium**, a spore abjoined from a pro-mycelium.
- Sporocarp**, a fructification, often the result of a sexual act, in which spores are produced, as in Red Sea-weeds and Fungi. Also used of the sporangial receptacles of the Hydropteridæ.
- Sporogonium**, in Mosses; the so-called 'moss-fruit' with its appendages, consisting mainly of the capsule and seta or stalk.
- Sporophyte**, that stage in the life-cycle of a plant which bears the spores. Cf. *Oophyte*.
- Spur**, an excavated slender continuation of some portion of a flower, usually containing nectar.
- Squamiform**, scale-like.
- Squamigerous**, furnished with scales.
- Stamen**, the male organ in a flower, which produces pollen. It consists of the filament or stalk, and the anther, in which the pollen is contained and which is supported by the filament. The stamens collectively form the andrœcium.
- Staminate**, having stamens.
- Staminiferous**, bearing stamens.
- Staminode**, a sterile stamen.
- Standard**, in papilionaceous flowers, is the unpaired, posterior petal.
- Sterigma**, the tube or stalk-like branch from which conidia are abstricted.
- Stigma**, that portion of the pistil which receives the pollen.
- Stipules**, paired foliaceous appendages of the leaf-base.
- Stirps cirrhosa**, a tendril-bearing stem.
- Stirps clathrata**, a lattice-forming stem. See vol. i. p. 678.
- Stirps fluctuans**, a floating stem.
- Stirps humifusa**, a prostrate stem.
- Stirps palmaris**, a standard-stem, i.e. an erect, unbranched stem.
- Stirps plectens**, a weaving stem. See vol. i. p. 671.
- Stirps radicans**, a stem which climbs by means of roots.
- Stirps volubilis**, a twining stem.
- Stock**, the parent forms from which a hybrid is derived.
- Stolon**, or **Stolo**, a procumbent stem which bears buds which take root; the buds are more frequent and the internodes shorter than in the runner.
- Stoma**, an intercellular space or pore in the epidermis which, bounded by adjustable guard-cells, forms the means of communication between the lacunæ of the plant and the outside air.
- Stratification**, the layering of cell-walls or starch-grains.
- Stroma-starch**, in certain Algæ (e.g. Hydrodictyon), the fine-grained starch deposited throughout the chlorophyll-body, which plays a different part in the economy of the plant from that deposited around the pyrenoid. Cf. vol. ii. p. 640.
- Style**, the usually attenuated prolongation of an ovary upon which the stigma is borne.

Sub-capitulum, a secondary capitulum.

Suberin, a corky substance; the substance or group of substances present in cuticularized or corky cell-walls.

Subex, a stem bearing scale-leaves.

Succulent, fleshy, pulpy.

Sucker. See *Surculus*.

Suffrutex, an under-shrub; a woody plant of quite humble growth.

Suffruticose, somewhat shrubby.

Surculus, or **Sucker**, a shoot arising from a subterranean base.

Suspensor, in Flowering Plants and in Selaginella; the filament of cells at the lower extremity of which the embryo arises.

Suture, a line of union, very frequently the line along which dehiscence also takes place.

Swarm, a social aggregate of simple organisms which live together but are not attached to any substratum.

Swarm-spore, a motile, ciliated, asexual reproductive cell destitute of a cell-membrane.

Switch-plant, a plant with reduced or wanting leaves, the shoots of which are green and subserve the functions of leaves.

Symbiosis, the association of two organisms which live together in intimate connection, both contributing to their mutual welfare.

Syncarpous, said when the carpels of a gynoecium are united.

Synconium, the fleshy excavated inflorescence of a Fig.

Synergidae, two naked cells situated at the micropylar end of the embryo-sac, and assisting in the passage of the male cell to the egg in porogamic fertilization.

Syngenesia, the 19th class of the Linnean system.

Syngenesious, having coherent anthers.

Systole, the rhythmic contraction of a contractile vacuole.

Tagmata, aggregates of micellae.

Tapetal cells, the layer of cells immediately external to the archesporium, and becoming latterly disorganized with the maturing of the spores (or pollen-grains).

Teleutospore, in Uredineae, a resting-spore which on germinating gives rise to a pro-mycelium or basidium.

Tenaculum, the clasping, rosette-like clamps of *Struves*, by means of which independent branches are held together.

Tendrill, a filamentous branched or unbranched organ, usually sensitive to contact, by means of which a plant climbs.

Tentacle, an irritable hair or emergence on a leaf, as in *Dionaea*, *Drosera*, &c.

Terete, round, i.e. circular in transverse section.

Ternary hybrid, the plant resulting from crossing a hybrid with a species different from either of its parent forms.

Ternate, used of compound leaves with three leaflets, one terminal and two lateral.

Testa, the integument of a seed, often arising from the outer of the two ovular coats.

Tetrad, a group of four cells (e.g. spores, pollen-grains), usually arranged in the four corners of a 4-sided pyramid (tetrahedron).

Tetradynamia, the 15th class of the Linnean system.

Tetradynamous, used of stamens when there are six, of which four are longer than the other two—as in Cruciferae.

Tetraspores, the asexual spores of Red Sea-weeds, usually aggregated in clusters of four.

Thalamus, the floral receptacle.

Thallidium, a vegetative reproductive body, especially amongst Thallophytes and Muscineae.

Thallus, a vegetative body without differentiation into stem and leaf.

Thermal constants of vegetation. See vol. i. p. 557.

Tissue, a continuous aggregate of cells having a common origin.

Tomentose, felty or invested in tomentum.

Tomentum, dense matted investment of woolly hairs.

Torus, (1) the floral receptacle; (2) the thickening on the pit-closing membrane of a bordered pit.

Trabeculae, folds or ridges projecting into a cell from the wall; the term also given to strings of filamentous cells bridging intercellular spaces.

Tracheids, elongated, pointed, and more or less lignified cells occurring in wood.

Transpiration, the act of exhaling aqueous vapour from foliage or other portions of plants.

Trichoblasts, fusiform hard-walled cells. Not a good term.

Trichogyne, the filamentous portion of the female sexual apparatus of a Red Sea-weed, which receives the spermatia.

Trichome, a hair-like or similar outgrowth of the epidermis.

Truncate, appearing as if cut short at the tip.

Trunk, a main stem.

Tuber, a subterranean, somewhat fleshy shoot.

Tubercle, a small excrescence.

Tumescant, becoming enlarged, distended.

Turgescence, **Turgidity**, the state of tension set up within a cell owing to the pressure of the osmotic cell-contents upon the elastic cell-wall.

Turion, a subterranean budding shoot, especially in perennials.

Umbel, an inflorescence in which a cluster of flower-stalks arises all from the same point.

Unguiculate, narrowed at the base into a claw: used of petals.

Urceolate, hollow and contracted at or below the mouth like an urn.

Uredospore. See vol. ii. p. 686.

Utricle, an archaic term for a parenchyma-cell.

Vacuole, a cavity in the protoplasm containing cell-sap.

Vagina, the sheathing portion of a leaf-base.

Valvate, having valves; opening by valves; also, used of the arrangement of the parts of a flower-bud when they just meet but do not overlap. Cf. vol. ii. p. 210.

Valve, (1) in flowering plants, the pieces into which a capsule breaks are termed valves; also the movable flaps in the dehiscence of anthers; (2) in Diatoms, the valves are the halves of the silicified membrane or shell, also called *frustules*.

- Variation**, a term employed to designate the disposition of two or more colours in the petals, leaves, and other parts of plants.
- Vascular bundle**, a continuous strand of vascular tissue, consisting either of xylem or phloem, or of both. Not infrequently sclerenchymatous elements are associated with the bundle, when it is termed a fibro-vascular bundle.
- Vascular elements**, cells or vessels whose main function is the distribution of water or formed food-substances. The chief of them are the vessels and tracheids of the wood, and the sieve-tubes of the phloem.
- Velum**, in *Isoetes*; the indusium-like membrane which covers the sporangium.
- Velum parziale**, in *Hymenomycetes*; the veil stretching from the stipe to the edge of the pileus. It often remains as the annulus.
- Velum universale**, in *Hymenomycetes*; the membranous wrapper inclosing the whole fructification.
- Venation**, the arrangement or pattern of the vascular bundles in a leaf.
- Ventral canal-cell**, the small cell which is cut off from the central cell of an archegonium immediately below the neck.
- Ventricose**, unequally swollen.
- Vernation**, the arrangement of the parts in the bud, especially a vegetative bud.
- Verrucose**, covered with warts.
- Versatile**, turning freely on its support.
- Verticillate**, arranged in a whorl.
- Vessel**, a tube consisting of cells which have become confluent by the partial or complete absorption of the intervening walls. They are common in the wood of *Angiosperms*.
- Viviparous**, term applied to plants the seeds of which germinate whilst still on the parent plant.
- Volva**, same as *velum universale*.
- Whorl**, a series of appendages arranged in a circle around an axis.
- Witches' Broom**, a form of gall found on the Silver Fir and other Conifers; sometimes applied to the bird's-nest-like hypertrophies on the Birch, &c.
- Wood**, the hard, lignified portion of the vascular tissue otherwise known as the *xylem*. It contains tracheids, woody fibres, and wood parenchyma, though not all of these are necessarily found in the wood of any given plant.
- Xenogamy**, pollination between flowers growing on different individuals of the same species.
- Xylem**, the woody portion of vascular tissue. See *Wood*.
- Zooglyca**, a solid gelatinous colony of Bacterial organisms.
- Zygomorphic**, applied to flowers which are symmetrical about one plane only, or can be cut into similar halves in only one plane.
- Zygospor**, a spore formed by the union of two gametes.
- Zygote**, a general term for the product of fusion of two gametes.
- Zygozoospore**, the motile stage of a zygote, the product of fusion of two motile gametes.

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